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High-Temperature Film Processing

Drying Film by Turbulent Air

Local TV Transmission

Magnetic Recording on Film

Carbon-Arc Screen Light

Theater TV Equipment

Projection Kinescope

Installing Theater TV

American Standards

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High-Temperature Film Processing

Its Effect on Quality

By Richard Hodgson and Jack Hammer

The processing of motion picture positive film by high-temperature developers and fixing solutions, and subsequent drying by turbulent air, results in film quality which is superior in some respects to film processed by conventional laboratory methods. Positive pictures, printed from an original camera negative, were processed by conventional techniques and by high-temperature methods.

METHODS and techniques to reduce the time required for processing of motion picture film have been investigated for a great many years, but the problem has received accelerated attention in the last five years. The increased interest in the problem primarily comes from three fields: (1) television film recording, (2) military applications, and (3) theater television.

Paramount Pictures' interest has been primarily in the rapid processing of television film recordings and theater television. The first rapid processing system was developed by Paramount five years ago and it processed and dried film in approximately three minutes. Continued development effort has resulted in this time being reduced to 25 sec by using a high temperature (120 F) saturated solutions of caustic developers and fixers and turbulent air drying.

The development work on turbulent high-velocity air drying was done jointly by Paramount and Raytheon Manufacturing Co. The following paper in this JOURNAL describes in detail this new technique. Currently theater television equipments which Paramount is constructing and selling include this new type drier. Figure 1 shows a typical installation of the Paramount system, including the turbulent air drier.

In shrinking the complete film processing time from the conventional commercial laboratory practice of approximately 40 min to 1% of that (25 sec), it was expected that to some degree the quality would suffer and that the print life would be short. This, however, has not been the experience with the millions of feet of film that has been processed in this manner by Paramount.

Presented on October 17, 1950, at the Society's Convention at Lake Placid, N.Y., by Richard Hodgson and Jack Hammer, Paramount Pictures Corp., Times Square, New York 18. For discussion, see the consolidated discussion following the next paper in this JOURNAL.

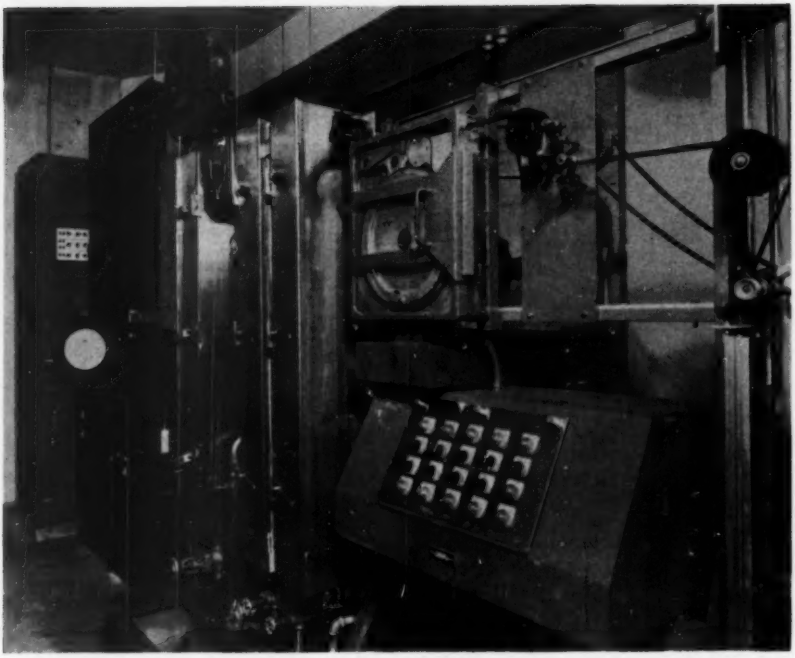

Fig. 1. The Paramount system, including turbulent air drier.

To demonstrate these results, two prints were made in an identical manner from an original camera negative of a "Sportlight" short. The same printer light setting was used in each case. One was processed by the conventional commercial laboratory procedure in 40 min with a 3½-min carbonate developer at 68 F. The other print was processed and dried in Paramount's high-speed equipment in 25 sec. The gamma of both prints is the same.

(At the Convention, identical sections from each print were projected and the audience was asked to state which print had the higher quality. Approximately 85% of the members attending the session voted that the print processed in 25 sec had superior quality.)

Photomicrographs (445×) were made of identical portions of picture frames from both the 40-min (Fig. 2) and 25-sec (Fig. 3) prints. Close examination of these photomicrographs indicated that no detectable difference in grain size exists. The grain size is approximately 1.2 microns in each instance.

One general film processing technician is required to operate the equipment. Chemicals are packaged in formula proportions so that only simple water mixing is required. This type of equipment is now in commercial operation as part of the theater television installations in Detroit, Minneapolis, Toronto, Chicago and New York, and additional installations are underway.

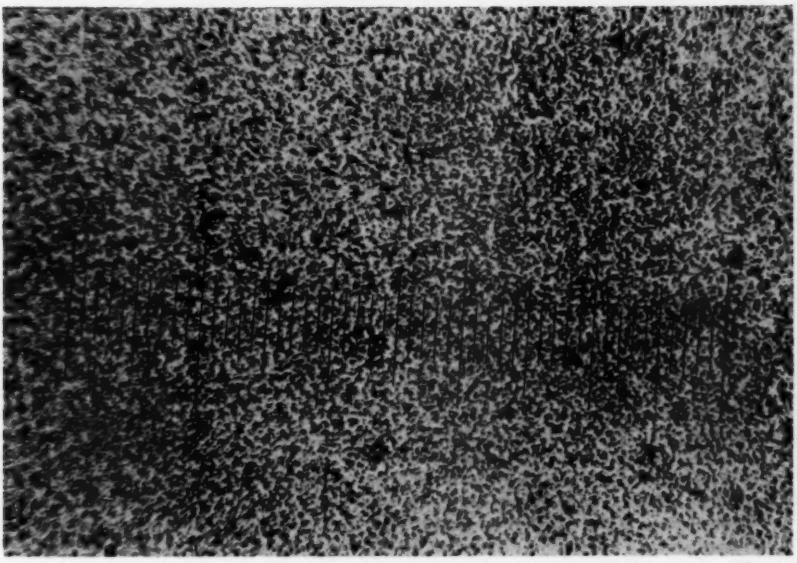

Fig. 2. Photomicrograph of film processed 40 min.

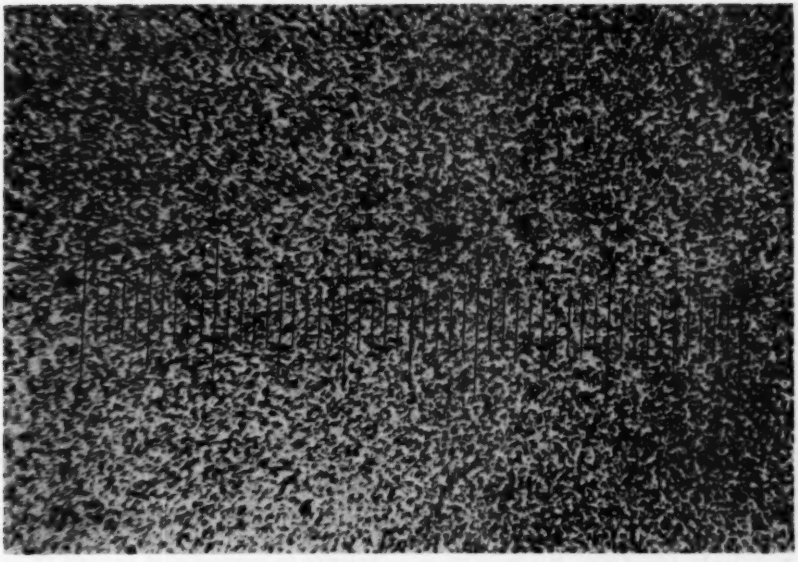

Fig. 3 Photomicrograph of film processed 25 sec.

Ultrarapid Drying of Motion Picture Film by Means of Turbulent Air

By Leonhard Katz

The problem of rapid processing of motion picture film has received considerable attention in the last decade. Although considerable study has been made of various methods to increase the speed of developing, fixing and washing, relatively little effort has been expended to improve the speed of drying. A description is herewith given of a number of different equipments which were designed after a theoretical investigation had been made of the drying problem. These equipments permit the ultrarapid drying of motion picture film in a convenient manner with extremely low distortion. One application of these units has been incorporated in the Paramount Theater-Television Units for the rapid processing of 35-mm film.

Basic Theory of Mass Transfer

MOTION PICTURE FILM can be considered as consisting of a base which absorbs practically no water and a gelatin layer which absorbs a very large amount of water. The drying of motion picture film requires that the water molecules diffuse out of the gelatin layer to the surface where they can be carried off by the surrounding medium. The rate of evaporation will be completely controlled by the rate of mass transfer of the water through the gelatin and through the surface layer between the gelatin and the surrounding medium.

In order to study this problem more closely it is well to consider the general theory of mass transfer between a solid substance (containing a liquid agent) and a gaseous surrounding, as shown in Fig. 1. From this general theory it will then become apparent which parameters can be varied to obtain the maximum rate of mass transfer and so obtain a maximum speed of drying.

It has long been recognized that in a heat and mass transfer problem the heat and mass transfer will depend on a number of variables as follows:

1. The area of contact over which heat or mass transfer takes place.
2. The driving force, i.e., the temperature difference in case of heat transfer, or pressure difference in case of mass transfer.
3. The resistance to mass or heat transfer which is proportional to the thickness of the stagnant layer existing at the dividing surface between the two media.

The first two variables have usually been well recognized and it is the usual practice to increase heat or mass transfer by increasing the surface area or

Presented on October 17, 1950 at the Society's Convention at Lake Placid, N.Y., by Leonhard Katz, Raytheon Manufacturing Co., Waltham 54, Mass.

Symbols, Definitions, Dimensions and Values

A = area normal to heat or mass transfer, sq ft
B = thickness of stagnant layer, ft
C_p = specific heat = 0.240 Btu/lb. °F = 0.514 w/cfm − °C for air at 100 F
D = equivalent diameter, $D = 4s/p$, ft
E_e = rate of mass transfer, lb/hr $E = 3.18 \times 10^{-4} \times Jm$, for water evaporation
f = dimensionless fluid flow friction factor; $f = 0.046/Re^{0.2}$
g = acceleration of gravity = 32.2 ft/sec² on earth
h = wall-to-fluid heat transfer coefficient, Btu/hr − sq ft − °F
J = film speed through drier, fpm
k = thermal conductivity = 1.56×10^{-3} Btu/hr − ft² − (°F/ft) for air at 100 F
L = length of film exposed to turbulent air
m = mass of water in film sample
M = molecular weight
n = number of ducts carrying air
p = perimeter of air-carrying duct
Pr = Prandtl number, dimensionless, defined as $3{,}600\, C_p\mu/k$
R = universal gas constant
R^* = gas constant per lb; for water vapor $R^* = 4.05 \times 10^{-2}$ ft³ − atm/°R − lb · H_2O
Re = Reynolds number, dimensionless, defined as $DV\rho/\mu = 4w/\mu p$
T = temperature. T_w = average over wheel; $R° = (460 + °F) = (492 + °C \times 1.8)$
U = air volume, cfm; $U = nVs$
V = air velocity, fpm
W = mass flow $W = 60\, U\rho$ lb/hr = $U\rho/60$ lb/sec
α = proportionality constant
δ = molecular diffusivity = 0.94 sq ft/hr for water vapor in air, at 100 F
μ = viscosity = 1.29×10^{-6} lb/ft-sec for air at 100 F
ρ = density = 7.1×10^{-2} lb/cu ft for air at one atm and 100 F
ϕ = partial pressure, atm; for water vapor in air, $\phi = 1.61 \times$ (absolute humidity)
θ = time

increasing the driving force, i.e., raising the temperature.

The third variable which takes into account the resistance to heat or mass transfer in the stagnant layer, has not always been fully recognized, and it will be shown here that a considerable improvement in rate can be obtained by reducing the thickness of the stagnant layer. This will be the case especially where the stagnant layer is the controlling factor as in the drying of motion picture film.

The stagnant layer can be considered as a relatively nonmoving layer of air which has the vapor pressure and temperature of the liquid on one side and the vapor pressure and temperature of the gas on the other side. It should be recognized, however, that the stagnant layer may not always be the controlling factor, so that care must be taken in applying this theory to other drying problems.

The drying process can be considered as a phenomenon normally included in the field of molecular diffusion. In

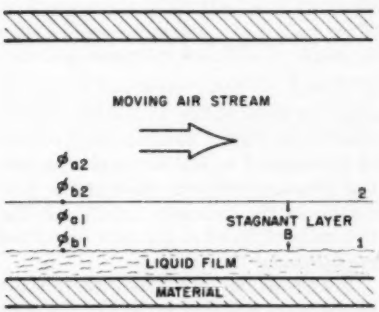

Fig. 1. Schematic drawing of the theory of mass transfer between a solid substance (containing a liquid agent) and a gaseous surrounding.

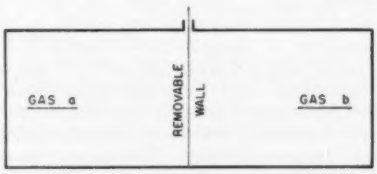

Fig. 2. Schematic drawing of the general theory of diffusion of gases.

order to get a better understanding of the problem, a short review of the theory of molecular diffusion is given here.

General Theory of Diffusion*

Let us consider two gases, a and b, as shown in Fig. 2, separated by a wall, at equal pressure and temperature. If the wall is removed, the gases will mix rapidly even though no external force is applied. It is apparent that an internal force of some sort is at work here, and the process by which the gases mix is called molecular diffusion. It has been assumed in elementary theoretical discussions that the molecules of the gases are extremely hard little balls, that their velocity has a Maxwellian distribution, and that the mean free path is very small. Maxwell assumed that the resistance to diffusion will be a function of the number of molecules in gases a and b, the difference in flow velocity, and proportional to the length of the diffusional path. The original equation as proposed by Maxwell was:

$$d\phi_a = \alpha_{ab} \frac{\rho_a}{M_a} \frac{\rho_b}{M_b} (V_a - V_b)\, dx \quad (1)$$

Under conditions of equal molal diffusion, and assuming that the Gibbs-Dalton law holds and that the gas is a perfect gas, it can be shown that:

$$\frac{E_a}{A\, M_a} = -\frac{RT}{\alpha(\phi_a + \phi_b)} \frac{d\phi_a}{dx} = -\frac{R^2T^2}{\alpha M_a (\phi_a + \phi_b)} \frac{d\rho_a}{dx} \quad (2)$$

where R is the universal gas constant. The diffusivity

$$\delta = \frac{R^2T^2}{\alpha(\phi_a + \phi_b)} \quad (3)$$

is now a characteristic which can be compared to thermal conductivity in heat transfer equations.

The diffusion of two gases can be investigated by making the following assumptions:

1. Equal molal flux;
2. Gibbs-Dalton law holds;
3. Gas is a perfect gas;
4. Pressure is constant; and
5. Temperature is constant.

For the general case of equal molal diffusion of a gas, a, into a gas, b, and a gas, b, into a gas, a, the following equation can be written:

$$\frac{\partial \phi_a}{\partial \theta} = \frac{R^2T^2}{\alpha(\phi_a + \phi_b)} \frac{\partial^2 \phi_a}{\partial x^2} = \delta \frac{\partial^2 \phi_a}{\partial x^2} \quad (4)$$

For the special case of the diffusion of a gas, a, through a stagnant layer of gas, b, we can assume that the flux of gas b is zero and the equation becomes as follows:

$$\frac{E_a}{A} = \frac{\delta(\phi_a + \phi_b)}{R^*\, TB} \left[\frac{\phi_{a1} - \phi_{a2}}{\phi_{bm}}\right] \quad (5)$$

where R^* is the gas constant converted for mass of water vapor,

$$\text{where } \phi_{bm} = \left[\frac{\phi_{b2} - \phi_{b1}}{\ln (\phi_{b2}/\phi_{b1})}\right] \quad (6)$$

It should be noted that gas b remains stagnant because the molecules of gas a tend to carry gas b along in the direction of diffusion of a, but the resulting partial pressure gradient of b causes b to diffuse in the opposite direction. The two rates of travel of gas b are equal and opposite and thus cancel.

For the drying of solids it can initially be assumed that the surface of the solid is always wet and that the rate of drying is entirely governed by the rate of diffusion from the surface. This is true initially until a certain point has been

---

* *Note:* Only the results of a rather lengthy mathematical treatment are given in this paper. For an exact derivation of the following equations the reader is referred to: (1) Lecture Notes, Course 2:43, Prof. J. Kaye, Massachusetts Institute of Technology; and (2) "Engineering Report on High-Speed Turbulent Air Film Dryer," (Private Doc.) Raytheon Manufacturing Co., January 19, 1950. The general theory of turbulence and its effects have been discussed in a large number of papers, most of which are listed in the Bibliography.

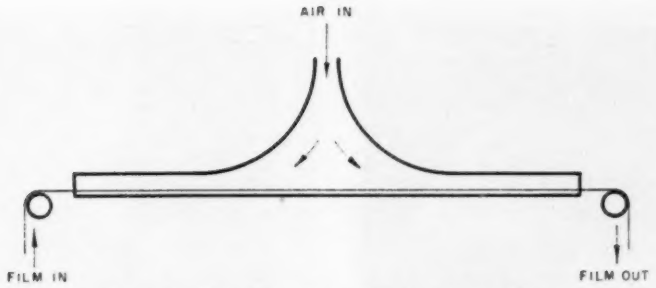

Fig. 3a. Experimental setup for film drier.

reached, whereafter the drying is determined by the rate of diffusion of liquid through the solid to the surface. The mass transfer when the surface is wet is governed by:

$$E_a = A \frac{\delta(\phi_a + \phi_b)}{R^* TB} \frac{(\phi_{a1} - \phi_{a2})}{\phi_{bm}} \quad (7)$$

For the rate of diffusion from a layer of liquid to gaseous surroundings, moving in turbulent flow, the following equation has been established experimentally by Gilliland.*

$$\frac{D}{B} = .023(Re)^{0.83}(Pr)^{0.44} \quad (8)$$

It can be seen from Eq. (7) and (8) that the fundamental parameter in mass transfer is the Reynolds number, a dimensionless quantity depending on the flow and physical properties of air, and on the geometry of the duct through which the air passes. We also note that this equation contains B, which is the effective stagnant air-layer thickness through which the water must diffuse. If we assume that the rate of evaporation is not limited by the diffusion of liquid through the solid, that is that the surface is always wet, an increase in the rate of evaporation can obviously be obtained by reducing the thickness of the stagnant layer, B. This, of course, can be done by choosing the parameters in Eq. (7) and (8) in such a fashion that the Reynolds number is very large and the diameter, D, is very small.

The total rate of evaporation of the liquid through the stagnant layer is given as follows:

$$\frac{E}{A} = \frac{\delta(\phi_2 - \phi_1)}{560\, B\, R^*} \left[\frac{1}{1 - \phi_M}\right] \quad (9)$$

where ϕ_1, varying along the length of the drier, is the partial pressure of water in the air stream, ϕ_2 is at 100% relative humidity at the surface of the film, and ϕ_M is the logarithmic mean of ϕ_1 and ϕ_2. The final bracket in Eq. (9) is the effect of the stagnant air. This bracket can be dropped out as long as $\phi_M \ll 1$, as is the case in most of our applications, where a total pressure of 1 atm is maintained. 560 R is used as the temperature, T, since δ was found at 100 F and δ/T remains nearly constant in the operating range.

It can be seen that the amount of water evaporated will be a function of the diffusivity of the material, δ, the log mean partial pressure difference between the water and the air, and the thickness of the stagnant layer, B.

By proper mathematical manipula-

* Lecture Notes, Course 2:43, Prof. J. Kaye, Massachusetts Institute of Technology.

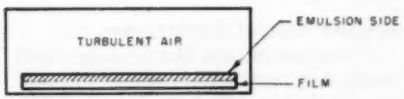

Fig. 3b. Cross section of tube for turbulent-air film drier.

Fig. 4. Type K-3 turbulent-air high-speed film drier.

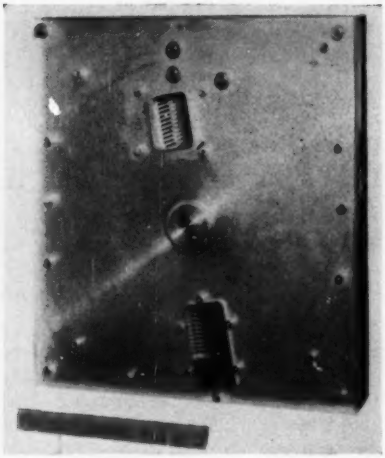

Fig. 5. Rear view of K-3 film drier showing turbulent-air heat exchanger

tion this can be reduced to the following simplified equation:

$$E = 2.65\ U(\phi_2 - \phi_{1A}) \left[1 - e^{-6.88 \times 10^{-3}/BU}\right] \quad (10)$$

We notice that this equation contains only those variables which are readily measurable, i.e., E, U, ϕ_2, and ϕ_{1A}. The quantity, B, which is still in this equation can be eliminated by combination with Eq. (8). By substitution and by the introduction of suitable parameters, a proper design can then be chosen for a high-speed film drier. For example, for the film drier shown in Fig. 4 substitution of the design parameters resulted in the following equation:

$$\frac{1}{B} = 82.6\ U^{0.8} \quad (11)$$

This equation relates the thickness of the stagnant layer to the amount of turbulent air blown over the film in cubic feet per minute. To determine the total amount of water evaporated, an equation can be derived from the combination of Eq. (10) and (11) which results in the following expression:

$$E = 2.65\ U(\phi_2 - \phi_{1A})\left[1 - e^{-0.568/U^{0.2}}\right] \quad (12)$$

This equation is the final relation which expresses the amount of water evaporated in a specific length of film as a function of the relative humidity and the amount of air blown over the film. A graphic representation of this equation is shown in Fig. 7 as the dotted curve which shows the expected amount of water removal as a result of the application of the foregoing theories.

This indicates that it should be possible to build extremely compact equipment capable of drying motion picture film at high speed and moderate temperatures (approximately 50 C). The dotted curve in Fig. 7 was computed for an air flow of 107.5 cfm. Different results can be obtained if the air flow is also changed and a whole series of curves have been obtained showing the relationship of air flow, temperature and water removed.

Construction of Equipment

If motion picture film is to be dried rapidly by application of the theories previously described, a unit must be designed which will permit turbulent air to be introduced over the wet film.

The first experimental unit was therefore constructed which consisted of a rectangular tube as shown in Fig. 3a, with a cross section as shown in Fig. 3b. Air at a pressure of 3 psi was introduced at the center of the tube at a rate of approximately 150 cfm. The film was pulled through the tube by a conventional sprocket drive. Experiments with this unit during the early part of 1949 indicated that even with this elementary unit 35-mm film could be dried at a rate of 75 fpm, but a number of difficulties were observed. The film was scratched by the bottom of the rectangular tube and considerable flutter existed. Also at this large rate of evaporation the film was cooled to near the freezing point of water and this cooling caused breakage due to reduced elasticity of the film. Heating the air relieved the situation somewhat but the body of the film remained still very cool.

In order to overcome these difficulties a second unit was built as shown in Figs. 4 and 5. This unit consists of a wheel 16 in. in diameter over which the film was led, with the back side of the film resting on a wheel. Air was introduced in the rear of the unit and was first passed through a turbulent air heat exchanger contained in the wheel (see Fig. 5). This maintained the wheel at a sufficiently high temperature to prevent excessive cooling of the film due to evaporation. After the air had passed through the heat exchanger it then was introduced over the film where it passed from the top around both sides of the wheel to the bottom. A small channel in the left-hand bottom side of the wheel was used to dry the back of the film by forcing air along it to blow off any moisture droplets still retained on the back side of the film.

This unit operated quite satisfactorily and a very large amount of film was dried on this equipment at a rate of 100 fpm. This unit was also demonstrated in conjunction with the Paramount Theater-Television Equipment at a show in September 1949 for the Theatre Owners of America in Hollywood, Calif.

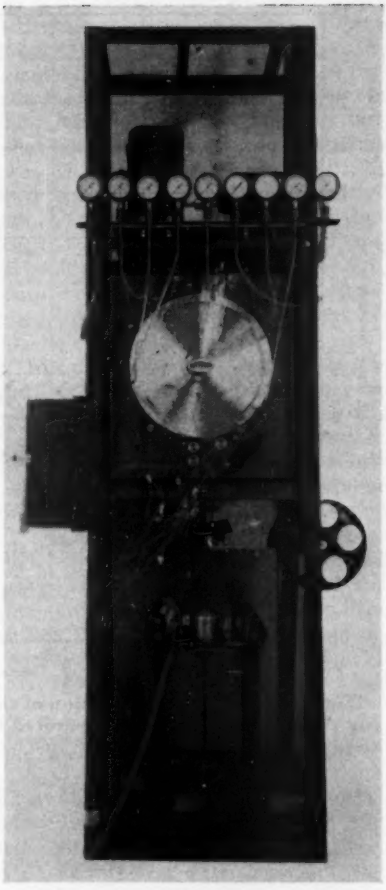

Fig. 6. Experimental setup of Raytheon K–3 film drier with water tank removed showing the film-wetting assembly.

After the demonstration this unit was returned to Raytheon for further study and an extensive experimental program was begun to determine the exact characteristics of this unit. A test setup was made as shown in Fig. 6 in

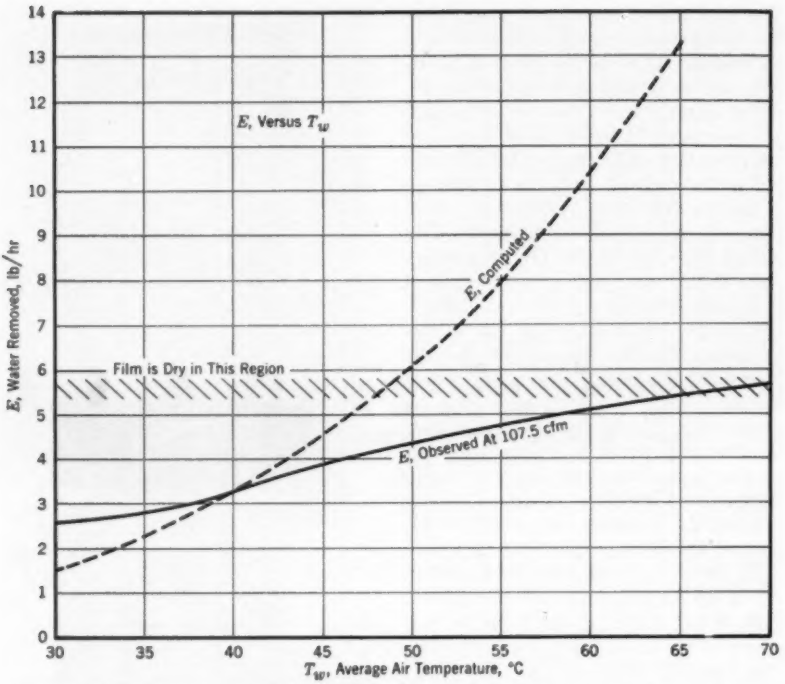

Fig. 7. Graphic representation of the theoretical and computed curves showing the amount of water evaporated from a specific length of film at given air temperatures.

which measurements were made of all the power going into the system, the total amount of water evaporated, and all the temperatures involved. The distribution of pressure and temperature was measured at a very large number of points along the wheel. As a result of these experiments it was found that the theoretical curve calculated from Eq. (12) and shown in Fig. 7 was not matched by the curve obtained in actual experiments.

An investigation of this discrepancy showed that the temperature of the film, and therefore the temperature of the water in the film, was considerably lower than the temperature of the air. It should be noted that the curve in Fig. 7 is plotted as a function of the average air temperature and it was believed initially that due to the use of the highly efficient turbulent air exchanger in the rear of the wheel, the wheel and film temperature would be equal to the air temperature. It was found, however, that the temperature difference between the air and the film was equal to the temperature drop encountered in the heat exchanger. Accurate measurements of the temperature of the wheel showed that the rate of evaporation followed the predicted theoretical curve within experimental errors, if the wheel temperature were plotted instead of the air temperatures. For instance, in the curve of Fig. 7, at an air temperature of 55 C, the wheel temperature was found to be 47 C; and at an air temperature of

65 C, the wheel temperature was found to be 48.5 C. This checks very closely with the computed curve. The deviation from the computed curve, as observed in the experiments, appears to be, therefore, solely a function of the temperature difference between the air and the wheel. It might be noted here that the difference in temperature between the wheel and film was very small and in the order of not more than 5 C.

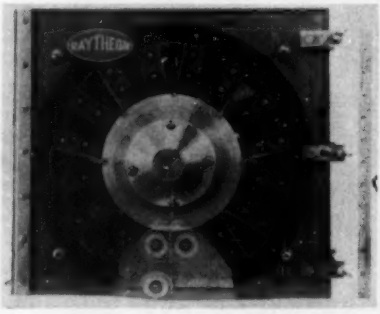

Fig. 8. Type K–4 turbulent-air high-speed film drier.

In order to assure operation of the wheel at the exact required temperature, a new model film drier (type K-4) was built as shown in Fig. 8. In this unit heating elements were installed in the wheel which were energized through slip rings. Approximately 2 kw of power was required to maintain the drum at the required temperature. The air was introduced directly into the slots in the rear of the unit and was forced over the film in a number of passages and exits in the front. The passages are formed by a number of movable blocks so that the duct width of the passage over the film can be varied. The diameter of this wheel was reduced to 6 in. from 16 in., since the calculations indicated that this would be sufficient to dry the film.

Satisfactory results were obtained with the K-4 film drier and considerable experimental data were obtained drying film at 100 fpm. However, an insufficient safety factor was allowed to permit the use of greatly different types of film. Up to this point the only film that had been used for the experiments was Du Pont Film, Type 628B. It was found that the amount of moisture which could be absorbed in the film during the photographic process varied considerably with different batches of film, with the amount and type of developer used, and with the amount of light exposure on the film.

In order to perform satisfactory experiments all tests described above were done with undeveloped film which was soaked in a wetting tank at constant temperature. It was found that only under these conditions could reproducible results be obtained.

The final design of a turbulent-air film drier which permits a sufficient safety factor for the use of almost any film of the 35-mm type is shown in Figs. 9 and 10. This unit (model K-6) incorporates a 14-in. wheel with approximately 3 kw of heaters inside the wheel

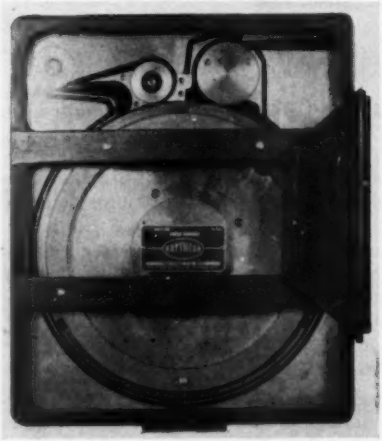

Fig. 9. Type K–6 turbulent-air high-speed film drier.

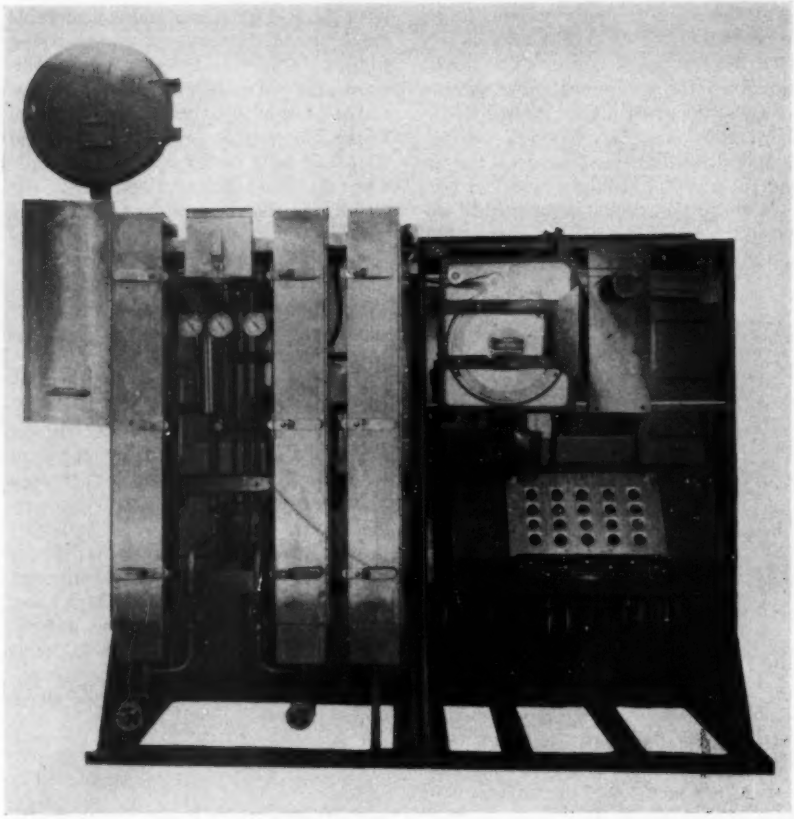

Fig. 10. K-6 film drier installed on Paramount Theater-Television Unit.

and approximately 2 kw of heat supplied to the air. A small Standardaire blower driven by a 3-hp motor delivers approximately 100 cfm at 5 psi. The capacity of this unit in water evaporated is approximately 10 lb/hr. Figure 10 shows this unit as mounted on the Paramount Theater-Television Unit.

Distortion

At the initiation of this project considerable doubt existed as to the possibility of survival of the emulsion when subjected to high-velocity air streams. It was believed that if the air velocity became too great the emulsion might be stripped off the film or that damage to the emulsion might result.

Although a large number of experiments have been performed in which air velocities have been observed as high as 550 mph over the film, not a single case of damage to the emulsion has been observed. On the contrary, measurements made at the Optical Research Laboratory, Boston University, with film dried in the Raytheon K-3 film drier, indicated that the distortion was considerably less than the distortion obtained by drying film by other means. It is

therefore believed that this method of film drying may be especially applicable where low distortion is of importance. It is believed that the freedom from distortion is the direct result of the uniformity of application of the turbulent air and of the rapidity with which the water is removed. Therefore all film shrinkages are uniform.

Application of Turbulence to Other Diffusion Problems

The general theory of diffusion can be applied to many other problems wherever the stagnant layer is the controlling rate factor in the diffusion problem. A number of different equipments have therefore been built for various applications using turbulent gases and fluids. It appears that turbulent air is an excellent medium to increase greatly the drying speed of most material in web form.

A very important application was found in the possibility of increasing the speed of photographic development, including the actual developing, fixing and washing. The speed of the photographic development process is greatly influenced by the speed of diffusion of various liquids into and out of the gelatin. It was found that a considerable increase in speed could be obtained by passing the developing, fixing and washing fluids over the film in turbulent form. These experiments will be the subject of a later paper.

Conclusions

A number of film driers have been developed in which turbulent air is used as a drying medium. It appears that satisfactory results can be obtained with such a unit in the ultrarapid drying of standard motion picture film in an extremely compact space. It was found that a wheel 14 in. in diameter will be satisfactory for film speeds up to 100 fpm. It was also found that the distortion in the film with this method of drying is very low.

Acknowledgments

Part of the work described in this paper was done in cooperation with Richard Hodgson of Paramount Pictures, Inc., whose valuable help and suggestions contributed greatly to its success. The unit 16 in. in diameter, shown in Fig. 5, was mounted on the Paramount 35-mm theater-television equipment and demonstrated in Hollywood for the TOA Convention at the Ambassador Hotel in September 1949. Approximately 26,000 ft of 35-mm film was processed through the 16-in film drier at a rate of 90 fpm during this convention with satisfactory results.

Part of the work described in this paper was done in cooperation with the Optical Research Laboratory, Boston University, with the assistance of Dr. D. E. Macdonald and Dr. R. C. Gunter, Jr., from that laboratory. The theoretical derivations described in this paper are based on the teachings of Prof. J. Kaye, Massachusetts Institute of Technology, whose valuable consulting services greatly helped in the speedy solution of many problems. The assistance of J. W. Belcher, W. F. Esthimer and J. F. Moore, who helped in the design of equipment and performance of the experiments, is gratefully acknowledged.

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DISCUSSION

F. N. Gillette: You mentioned that the turbulent fluid processing was considerably faster. Faster than what? How does it compare with the spray type of processing used in the Paramount equipment?

Mr. Katz: That is a difficult question to answer. The developing time in general has been rather vaguely defined. In order to get around that problem we set up our experiments as follows: The system consists of a chamber in which our photographic film wedge is suspended and we pump liquid developer out of a reservoir through the chamber and back into the reservoir again. We measure the temperature, pressure and velocity of the liquid developer so that we know the Reynolds number in the chamber over the film. We then compare the speed of developing under turbulent conditions with the speed of developing required by a similar photographic wedge hung in the reservoir under stagnant conditions. There is mild agitation in the tank under those conditions through liquids being pumped around. The ratio between the developing time under stagnant conditions and the developing time under turbulent conditions is called the improvement factor. It is a little early really to comment on this method since we have run only about 150 films through this turbulent chamber. The encouraging factor, however, is that the improvement appears to be a linear function of the Reynolds number and we have not found a leveling off of the curve anywhere.

E. W. Kellogg: [*condensed*] I want to ask Mr. Katz about the static film theory. I understand that a number of years ago Langmuir, during the development of the gas-filled incandescent lamp, concluded that in the circulating atmosphere around hot filaments there was a stationary film whose thickness was cut down by the rapidity of the current. Do you know of any evidence to prove whether there really

is a stationary film with a fairly definite thickness?

MR. KATZ: The thickness of the static film can actually be determined. It has been found that ultrasonic waves will also destroy the stagnant layer.

DR. KELLOGG: How do you know that the layer is really stagnant, with a definite boundary surface between it and the region of turbulent flow?

MR. KATZ: The only good answer we have for this is that the theory has not yet been disproved and everything we have found so far seems to follow the theory accurately. We don't measure the stagnant layer directly but indirectly by the results which we get, and everything that we have done so far lies within experimental error of our theory. Until the theory is disproved we more or less assume that we are right.

ROBERT M. CORBIN: Mr. Katz, I have one point I would like to make. In your first illustration, you showed film base as being more or less an inert material, which is far from the fact. In your process, I don't think this enters in at all, but if anyone should try to dry a film by your method after the conventional processing, they might get involved in some difficulty on account of the amount of moisture taken up by the film base. There is very little, if any, taken up in the rapid processing method; but if you had the film base saturated with moisture, and you didn't make a very great effort to drive the moisture out, at least to the same equilibrium at which you are going to keep the film, you would get differential drying in the roll and a buckling effect which has been encountered in the old type of processing in the past with disastrous results. So, this type of drying should be reserved for rapid processing, or at least modified to take care of moisture absorption if used with other types of processing.

MR. KATZ: The unit which we have built for Boston University under subcontract for the Air Forces takes 9½-in. wide super XX film which has a very heavy emulsion. The film is processed by conventional means with a total processing time of approximately 4 hr in which it is continuously immersed in liquid. It is then dried in the machine at a rate up to 70 fpm and comes out totally dry.

MR. CORBIN: My point is concerned with motion picture film particularly. If you roll it up on the reel, the film is under fairly high tension. You don't get drying in the center of the roll as rapidly as in the outside windings and you can also get the outside to dry down more rapidly and cause a sort of baggy effect in the center. Your edges become shorter than the center, with a buckling effect on the screen when you project it. There would not be a problem with anything like Aero film.

MR. KATZ: We have measured distortion rather carefully on Aero film. Very fine grid is superimposed on the film and then analyzed. We have found no such distortion as you mention.

MR. CORBIN: The distortion I am speaking of doesn't take place at the time of drying. It takes place during storage under rather high tension of rewinding, which is generally used for motion picture film. It is not a question of distortion at the time of drying, but of distortion effects after the ultrarapid drying.

MR. KATZ: We have not run into anything of that nature yet. It may be ahead of us.

JOHN G. STOTT: I have a couple of questions which I think could be tied up with one answer. Do you have any data on horsepower consumption of drying by this method compared to conventional methods?

MR. KATZ: The horsepower rating of the unit which is presently installed in the Paramount Theater-Television Unit is 7½ kw. The horsepower rating will always go up as the speed of drying increases since a certain amount of heat of evaporation must be supplied.

MR. STOTT: Do you preheat your air?

MR. KATZ: Yes, we preheat both our air and our wheel. The reason for that is that in the evaporation process both the air and wheel will cool off and if we don't heat the air and the wheel the film will be cooled to a point of excessive brittleness and break.

MR. STOTT: I also notice in your paper the conspicuous absence of data on relative humidity. Does it have any particular effect?

MR. KATZ: The satisfactory operation of the unit is independent of relative humidity of the air.

MR. STOTT: In other words, you get dry film with essentially saturated air.

MR. KATZ: We have done that, yes.

H. J. SCHLAFLY: You give figures of pressure and air on the first model. Do these hold true for the latest design?

MR. KATZ: No, they vary. The latest design uses a thinner opening than the first model. The latest design operates at 4½-lb pressure and something in the vicinity of 80 cfm for the total air consumption.

MR. SCHLAFLY: What are the requirements on the blower?

MR. KATZ: The actual horsepower required for the blower is approximately 3 hp. We have a 5-hp motor installed just to be safe.

MR. STOTT: Mr. Hodgson, with regard to your demonstration reel, truthfully I was astonished when you said that the first reel was processed by conventional means, whereas the last one was processed on your hot machine, because I have done some work in this rapid processing and have noticed that one of the effects (I wouldn't call it a defect) of the hot processing is considerable sharpening of the toe region of the sensitometric curve instead of a long sweeping toe, which is characteristic of 5302. It tends to sharpen it, which usually shows up as more glaring highlights, and I definitely thought that the first film, on the basis of its highlights, was the rapid processed one. Secondly, the rapid processing tends to create or produce very much of a blue-black tone as compared with the cold process, and once again I was fooled on that basis, because I thought the first film was rapid processed and the second one processed conventionally. Do you have any comments to make on that?

RICHARD HODGSON: Not particularly. The first portion was done by conventional 40-min processing. The last section was done in 25 sec.

MR. STOTT: Do you have any sensitometry on this?

MR. HODGSON: No.

VOICE: I have come to the opposite conclusion. Viewed from this distance, the second one had definitely more contrast. Also, the second one had more blue-black.

MR. STOTT: I don't think I was at optimum viewing position down here, but I got exactly the opposite reaction from yours. How did somebody in the middle feel about it?

VOICE: We couldn't tell the difference.

MR. HODGSON: Well, that is what we like to say. We would like to project them side by side too, but the facilities here don't lend themselves to this. The best we could do was to give you the photomicrograph slides in rapid succession for what that indicates in grain size. It doesn't take care of the other factors which you mention, however.

GEORGE LEWIN: Mr. Hodgson, do you happen to know whether this sound track was variable density or variable area?

MR. HODGSON: Area.

MR. LEWIN: Do you have any data as to whether either type of track will respond to this treatment in the same way?

MR. HODGSON: We normally use variable density. This negative happened to be variable-area track and we handled it the same way that we handled variable-density track. In other words, we developed it to a density of 0.2. We gave it no special treatment.

MR. LEWIN: Would you say that you can treat the negative just as successfully, or just the print?

MR. HODGSON: We make more negatives in the course of our recording of television shows than we do positives by about a factor of 7 to 1, and they are handled by the same method—different formulas, but the temperatures are the same.

NORWOOD L. SIMMONS: [*Question to Mr. Katz*] We assume that your remark that saturated air can be used must have applied to air saturated prior to its heating?

MR. KATZ: That is correct.

DR. SIMMONS: Secondly, from the front row I did note what I thought to be considerably more density fluctuations in the second print—nonuniformity, or what you might term not mottled, but some weaving density fluctuations which appeared just at the start. Did anyone else have such a feeling?

[*Several hands were raised.*]

DR. SIMMONS: There were several others who didn't seem to have the courage of their convictions when you asked for a vote.

C. R. FORDYCE: I'd like to ask Mr. Katz what maximum temperature the air reaches in the drying operation, and what temperature the film reaches?

MR. KATZ: There are a number of units in operation at the moment, not all of them are alike. In general, we try to maintain the film at a temperature of approximately 55 C. The air temperature varies depending on the design of the unit. If there is a heat exchanger in the rear it has to enter very much hotter to maintain the wheel temperature at the desired level of 55 C. In general, we try to maintain the air over the film at a temperature of 70 C. With the air running over the film at 70 C, the temperature of the film will remain at 55 C.

J. A. TANNEY: In answer to the question about the buckling effect or the in-and-out effect that you might get when viewing the projected picture, have you ever tried any of those films that have been in storage or which have been wound and rewound?

MR. KATZ: As far as the 9½-in. film drier is concerned, we have stored 9½-in. film for a considerable length of time after it has been dried in the machine, and we have not been able to find any difficulty so far. Maybe we haven't stored it long enough or reeled it and unreeled it enough. The film in the machine, however, gets wound up after considerable tension.

MR. TANNEY: I was referring to motion picture film. I don't suppose you have done much of that.

MR. HODGSON: The first real chance to observe this came when the first turbulent drier was used in connection with the demonstration we made last October in Los Angeles for TOA, and that reel or series of reels which we dried then we have shown to people as recently as last August, which was almost a full year later, and the projectionists have reported no trouble in running it through. It seems to handle just as a normal reel.

DR. KELLOGG: One more question occurs to me. What provisions do you make for keeping your air clean? It seems to me that this violent blowing would tend to deposit dust on your film unless some rather extraordinary filtering precautions were taken, or else re-using the air after precipitating out the moisture.

MR. KATZ: We have had that problem, especially at the point where the air is first introduced on the film. At that point the air has to go around a corner and any particles in the air would hit the film straight on. In our 9½-in. wide film drier we found that pitting of the film would occur if we purposely blew sand into the machine. Sufficient filtering, however, was obtained by means of an ordinary air filter similar to the one used in an automobile engine.

Supplementary Discussion*

The stagnant-layer theory is specifically based on the principle that the speed of diffusion of the liquids through the gelatin or other solids is sufficiently great so that the surface can always be assumed to be wet. If the surface of the gelatin is wet then the only resistance to diffusion will be posed by the thickness of the stagnant layer. At low temperatures the driving force is relatively small and the entire resistance to evaporation is governed by the thickness of the stagnant layer. The rate of evaporation will still be relatively small at low temperatures even if the stagnant layer is reduced because the driving force is relatively small. Of course, reduction in the stagnant layer will bring about a proportional increase in the rate of evaporation. Consequently, if, for instance, at low temperature the normal drying time for one section of film were 1 hr, and the stagnant layer were reduced to $\frac{1}{30}$ of its thickness by the application of turbulent air, then the drying time would be reduced to 2 min.

Inasmuch as the rate of evaporation is still relatively low, the rate of diffusion of the liquid through the gelatin is so small that the surface can be assumed to be wet at all times. If, however, the temperature is now raised, which increases the driving force, the rate of evaporation will be increased to a point

* Communicated by the author on December 14, 1950, in order to clarify points raised during the discussion.

where the diffusion through the gelatin itself will become the limiting factor, i.e., a point may be reached in which the surface layer of the gelatin closest to the gas side is relatively dry, whereas the bottom of the gelatin closest to the base of the film would be relatively wet.

The problem is then resolved into a transient diffusion problem in which a humidity gradient is set up through the gelatin. This humidity gradient will only become important when the rate of evaporation has been greatly increased. It was found experimentally that this limit becomes apparent when positive-type stock is dried in a time shorter than 1 sec or when negative stock is dried in a time shorter than 2 sec. In general, therefore, film driers must be designed in such a fashion that the emulsion of the film is exposed to turbulent air for a period of not less than 2 sec. The actual film speed that can be obtained can, of course, be made as large as one wishes by simply increasing the time during which the film is continuously exposed to turbulent air.

With reference to the extremely low temperatures realized in the use of the first model, it can be stated that this was not originally anticipated. It was hoped that as a result of the turbulence the heat transfer between the air and the film would be sufficient to maintain the film at room temperature. However, it was found that approximately 40% of the heat was supplied from the air and 60% of the heat had to be supplied by direct conduction or radiation into the film itself. Consequently, the heating of the back side of the film was necessary to maintain the film at room temperature or higher.

With reference to the use of raw film in the experiments, I would like to explain that a large number of experiments were first made with processed film which had been run through Paramount's 35-mm machine. It was found, however, that small changes in the developer or hypo concentrations plus small variations in the thickness and quality of the emulsion itself produced variations in water absorption of the film of approximately 50%. As a result it was not possible to use processed film in the experiments, as consistent data could not be obtained. A number of experiments were then performed in which the total water absorption of the processed film was checked carefully and the total spread in the water absorption figures was carefully noted. The experimental determination of the rate of evaporation at various temperatures and Reynolds numbers of the air was then performed on raw stock which again had been carefully measured as to its water absorption qualities. It was found that the amount of water absorbed in the raw stock was to a great extent determined by the temperature of the water in which it was immersed. During the experiments the temperature of the water was maintained at a point where the water absorption of the raw stock was approximately equal to the water absorption of the processed stock. Adequate corrections were then made in the design of the film drier to produce a safety factor which would compensate for the spread in the water absorption qualities of the processed stock, so that even under the worst conditions processed stock could be dried in the required time. Spot checks were made at various points during the experiments with the processed film to compare the result between processed film and raw stock at a number of points in the curves.

With reference to the type of film distortion which was measured and the methods used for measurement, I would like to defer the discussion of this to a later paper which is now in preparation in cooperation with Dr. R. C. Gunter of the Optical Research Laboratory, Boston University. Also, additional details concerning the actual design of film driers and general design charts will be presented in that paper.

Television Transmission in Local Telephone Exchange Areas

By L. W. Morrison

The functions of a video transmission system in a local exchange area in providing mobility for the pickup camera and interconnection with the intercity networks are discussed; and an analysis of some of the television transmission problems is presented. A description is given of the physical and electrical characteristics of the various types of cable facilities, the video amplifiers, and equalizers now employed; and an example of the television transmission performance obtained is included.

THE TELEVISION transmission distribution system in the local exchange area fulfills a most necessary function in the over-all television broadcasting system. The sole purpose of network broadcasting is to attract the greatest possible audience. The local video distribution system, as the means whereby the initial and final connection is accomplished, contributes to the efficiency of the network pattern in two ways: first, it allows greater mobility for the pickup camera, thus permitting a wider range of subjects and more attractive program material to be offered to the public; and second, it furnishes the means by which the program may be made available to viewers far outside the present restricted coverage of a television broadcast transmitter. In the future, it is believed, the local television system may in a similar fashion contribute to efficient distribution of televised material for theater consumption.

At present, the local video system is called upon to furnish the connection between the remote pickup camera and the master control area of the local studio, the connection between the studio and its local broadcast transmitter location, and the connection between the studio and the intercity network facility.

It is apparent that we are here dealing with a transmission facility which has two unique characteristics. First, we are concerned with relatively short distances, say 1000 ft to 20 miles; and second, the system is entirely a point-to-point transmission medium as contrasted with area coverage of the usual broadcast transmitter. In addition, the very nature of the function dictates that privacy of the connection be assured.

The Bell System presently employs both wire and microwave television transmission methods in the local telephone exchange area. The choice of medium here, as always, is one of

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economics. For example, in the Los Angeles, Calif., area all television broadcast transmitters are located on a mountain range overlooking the metropolitan area, approximately 20 miles from the Hollywood location of most studios. The terrain is such that microwave methods have an overwhelming advantage over wire circuits for the main circuit, though even here the final connections to the various broadcast transmitters on the mountain are made by wire circuits just as the studio-to-Hollywood Central Office pickup connection is made. In many other metropolitan locations the microwave line-of-sight requirement is difficult to achieve and in these cases wire television facilities are almost exclusively employed. In our opinion, wire and microwave television transmission techniques will tend to complement rather than compete in the service of providing a sound economic local point-to-point television connection.

The following discussion will be confined to the local telephone exchange area television transmission systems employing wire as the transmission medium. It is proposed to analyze the problem considering the terminal conditions, the characteristics of the cable plant, and the gain and equalization required. A description of the equipment now in use will be followed by a discussion of typical performance obtained.

Terminal Conditions

The television studio equipment which represents one terminal condition for a local video interconnection is generally operated on a 75-ohm unbalanced-to-ground impedance basis. This is a matter of economy of components and within the restricted confines of a studio area is permissible since the signal levels are relatively high and the transmission distances involved are small.

In the telephone plant where greater lengths of exposure to interfering electrical fields are the rule, the balanced-to-ground impedance is universally employed. The characteristic impedances of telephone cables which are available for video transmission purposes range from 90 ohms to about 140 ohms. The equipment design at present is based on a balanced impedance of 110 ohms.

The signal level available at the studio for transmission over a local interconnecting circuit has been generally of the order of 2 v peak-to-peak and the input level required at a television broadcast transmitter or at the input to the studio master control equipment has varied from 0.25 to 1 v peak-to-peak.

The signal level which is impressed on the telephone cable is maintained at the highest possible economic value to insure the best signal-to-noise performance. At present the common signal amplitude at the input terminals of a cable is generally of the order of 2 v peak-to-peak. In the television operating centers which represent the terminals of the intercity network a standard level of 1 v peak-to-peak across 110 ohms has been adopted.

The local video transmission equipment then must provide for the conversion of the signal from the form available at the terminal ends to one suitable for transmission over the telephone cable. This involves treatment of both impedance and signal levels.

Telephone Cable Characteristics

The character of the transmission medium exerts the primary influence on the design of the bulk of the equipment employed in local video interconnecting circuits. The characteristics involving impedance, attenuation versus frequency, and the shielding, as well as the pair location with respect to sources of induced unwanted interference, must be considered. The impedance and attenuation characteristic dictate the

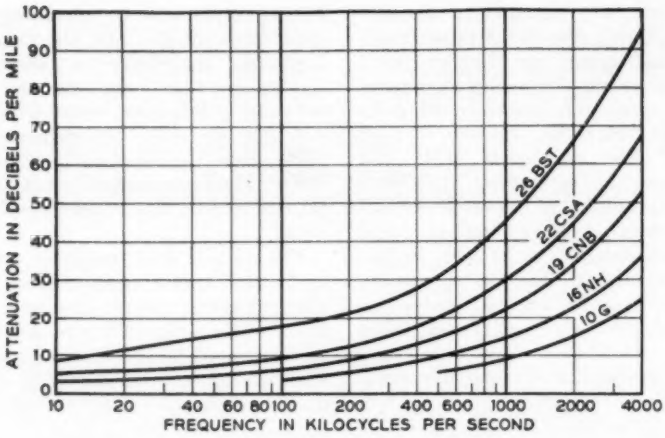


Fig. 1. Attenuation of paper-insulated cables at video frequencies.

type of termination to be employed and the degree of equalization required. The shielding properties of the cable, together with a knowledge of the degree of exposure to sources of interference, finally set the signal-to-noise performance of the circuit.

A wide variety of paper-insulated interoffice and subscriber cables exist in the telephone plant. Gauges ranging from No. 10 to No. 26 are employed with many available routes consisting of a composite of these. Figure 1 shows the attenuation-frequency characteristics for a number of cables which have been used for video purposes in the past. The loss at 4 mc (megacycles), which must be compensated for by equalization and gain, varies from about 25 to 95 db/mile for the types shown.

These paper-insulated pairs are adjacent to others, perhaps as many as 1800 in a single lead sheath, and are therefore subject to induced interference from signals in these associated message circuits. Impulse-type noise is commonly transmitted over a message circuit resulting in large measure from the complex switching operations of the modern telephone plant. In addition, low-frequency signals may be induced into the video pair from neighboring power circuits.

The minimum level to which the video signal may be attenuated involves the total interference level at hand and a signal-to-noise performance objective. With this information and a knowledge of the maximum undistorted power output of the video repeater or the transmitting terminal, the maximum usable gain required is determined. Then by a consideration of the attenuation characteristic of the cable, the repeater spacing may be computed.

For the paper-insulated pairs under consideration, impulse-type noise generally is controlling, and repeater gains of about 65 db result. For No. 26 gauge this will result in a repeater spacing of about 0.7 mile.

There is finally another restriction in the maximum gain which can be used in a video repeater. The coupling between the input and output of the repeater must be limited if unwanted regeneration effects are to be minimized. This coupling from output to input terminals via adjacent pairs limits the gain usually to the order of 40 db. This

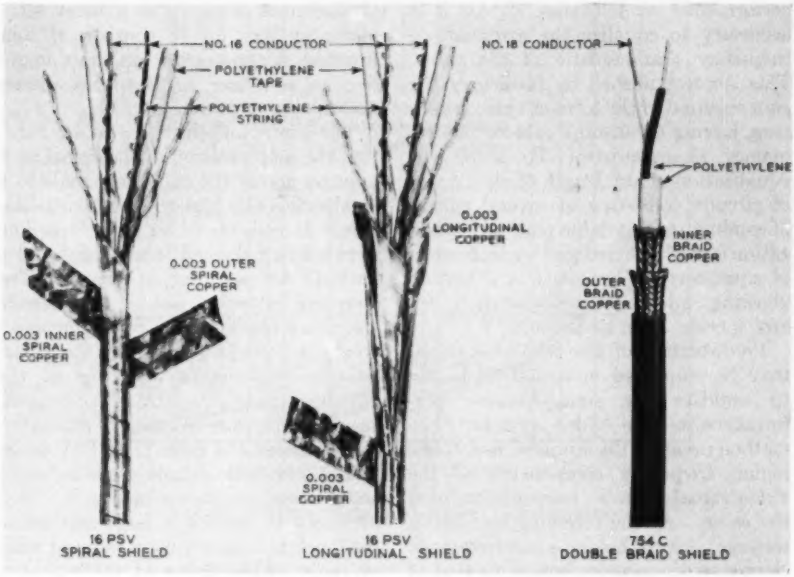


Fig. 2. Construction of shielded video cables for local exchange area use.

situation may be remedied by the use of separate cable sheaths at the input and output of each repeater.

At the present time the majority of video interconnecting circuits in the local exchange area employ a special shielded pair for transmission, thus reducing materially the restrictions present with paper-insulated telephone cables just discussed. Figure 2 illustrates the mechanical features of construction of some of these shielded television pairs.

The 16 PSV (polyethylene shielded video) pair uses polyethylene string and tape to support the 16-gauge conductors within a copper shielding tube. As shown, both spiral copper tape and a combination of spirally wound tape and a longitudinal seamed tube have been employed. Such a conductor is composited directly into an interoffice cable replacing about 20 of the paper-insulated pairs. A number of such 16 PSV conductors may be placed within a common lead sheath, the improved shielding allowing their use simultaneously in either direction for transmission.

For interior wiring within the central office and at the terminal ends of the circuit, as well as for temporary short outside routes, the double-braided flexible cable shown in Fig. 2 has been extensively employed. This cable has a solid polyethylene extruded core containing two No. 18 conductors.

The attenuation-frequency characteristic of the polyethylene dielectric type of video cables is given in Fig. 3.

When the shielded video cable is used the impulse-noise level is greatly attenuated and the allowable repeater gains may be increased. With an attenuation of 17 db/mile, as indicated in Fig. 3, it allows repeater spacings upward of 5 miles to be employed.

To provide adequate transmission

performance for television signals it is necessary to equalize the attenuation-frequency characteristic of the cable. This is accomplished by furnishing the gain required in the form of video amplifiers, having a constant gain-versus-frequency characteristic. To allow the equalization of any length of circuit and of circuits consisting of several gauges of conductors a variable plan for equalization is used. Fixed and variable units of equalizers are provided in a fashion allowing adequate compensation for any specific cable situation.

Predistortion of the television signal may be employed in certain instances to improve the signal-to-noise performance of the video system. The method involves the amplification of the higher frequency components of the video signal prior to transmission over the cable. At the receiving terminal a restorer network having a loss-frequency characteristic complementary to that of the predistorter is introduced. The signal is unaffected by transmission through these two networks while noise introduced into the cable circuit is attenuated by the restoring network. Figure 4 indicates the characteristics of the predistorter and restorer networks. An impulse-noise improvement of about 16 db is realized in practice.

Equipment Description

There are three basic equipment units which are required in a local wire television transmission installation. These include a transmitting terminal, a repeater, and the receiving terminal. The primary function of the transmitting and receiving terminals is one of conversion of the signal from the customer's equipment to a form suitable to the cable pair in the telephone plant. The repeater unit furnishes the bulk of the gain required to overcome the transmission loss of the cable and the means to properly equalize its loss-frequency characteristic.

The Video Repeater. The repeater arrangement is shown as a block schematic in Fig. 5. It consists of four functional components: an input amplifier, an equalizer, an output amplifier and necessary power supplies.

The input amplifier has as its function the amplification of the signal as it appears across the cable terminals to a level sufficiently high to permit equalization. It consists of an input coupling network, a balanced input stage and a cathode follower output circuit. The coupling network has a gain-versus-frequency characteristic which increases to about 13 db at 4 mc. This characteristic in conjunction with one of the equalizer units is capable of compensating for the loss-frequency characteristic of about $1\frac{1}{3}$ miles of 16 PSV cable.

The schematic details of the balanced input stage are shown in Fig. 6. It is arranged to provide a large amount of feedback to longitudinally induced noise voltages which arrive at the repeater. The longitudinal suppression here obtained is of the order of 75 db at low frequencies, the region of the most troublesome noise conditions. In addition, impedance balancing controls are provided to further minimize these effects. The voltage gain of this input amplifier is about 14 db and the output circuit is arranged to connect directly to the following equalizers on a 1000-ohm impedance basis.

The equalizer portion of the video repeater consists of three types of units: a basic equalizer whose loss-frequency characteristic in conjunction with the input amplifier coupling network will compensate for about 25 db of 16 PSV cable loss at 4 mc; a variable unit which will equalize 10 db of cable loss in 1-db steps and the fixed equalizer which will equalize a 10-db section of 16 PSV cable.

By using one or more amplifier coupling networks, and basic, variable and fixed equalizers, we have the means to provide equalization of any specific length of cable—limited finally by the gain capabilities of the repeater.

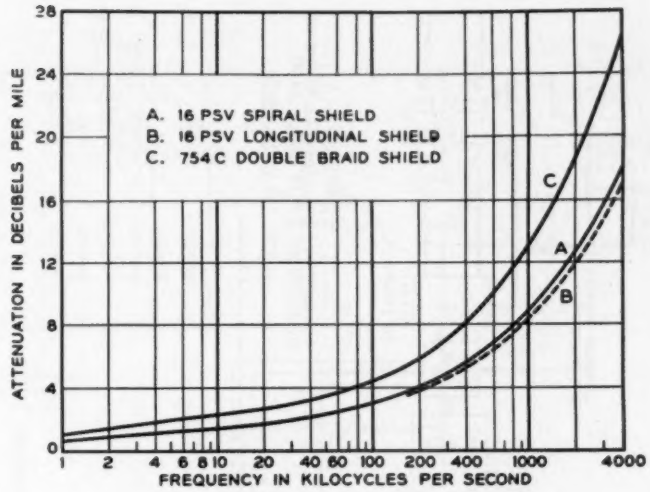


Fig. 3. Attenuation of shielded video cables.

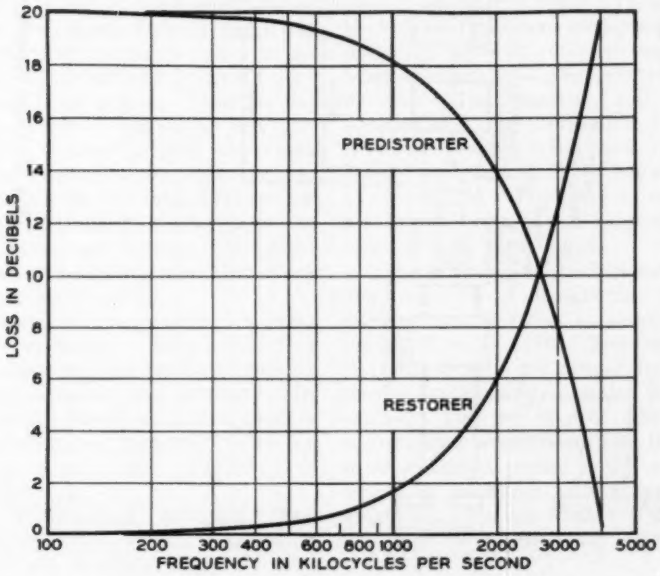


Fig. 4. Loss-frequency characteristics for predistorter and restorer networks.

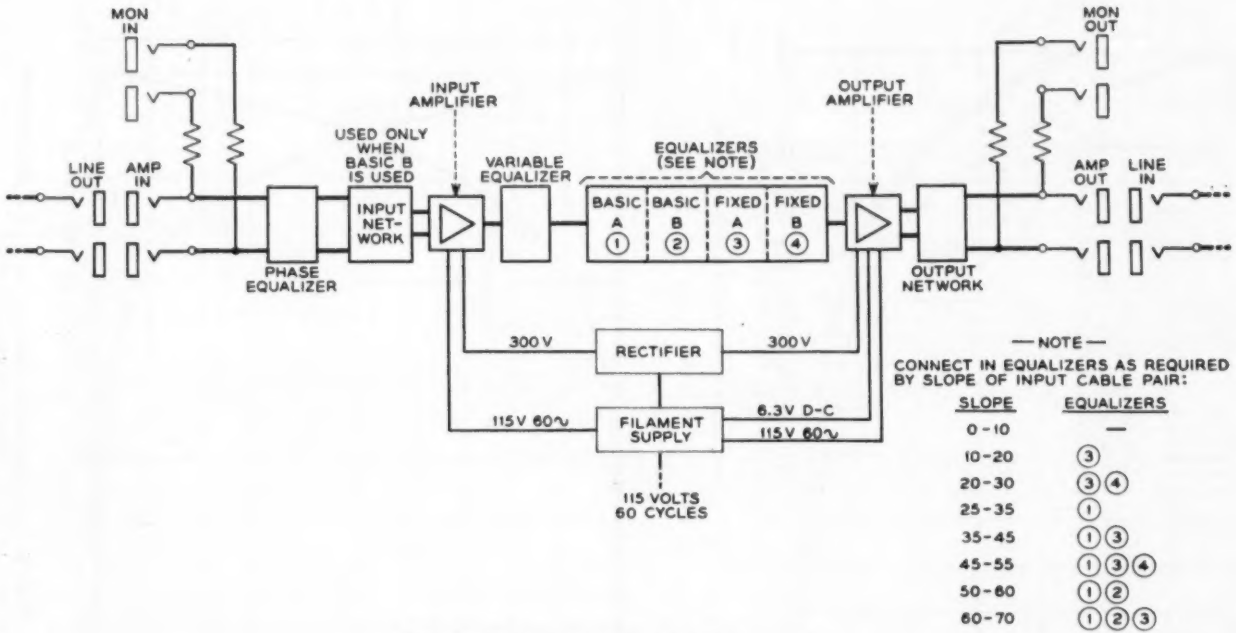


Fig. 5. Video repeater—block schematic.

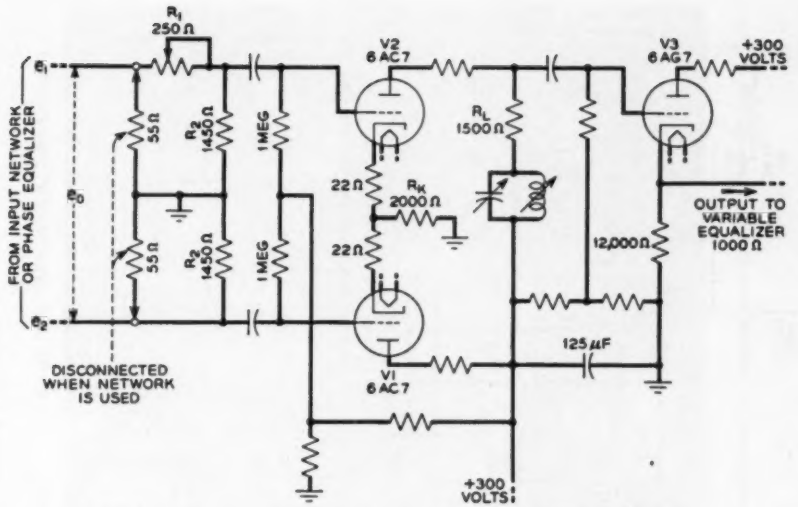


Fig. 6. Video repeater input amplifier—simplified schematic.

The output amplifier shown schematically in Fig. 7 provides 30 db of gain to the signal after it has been equalized and normally operates to furnish a 2-v peak-to-peak signal to the following cable section. Through the use of a network similar to that discussed in connection with the input amplifier a pre-equalized signal may be impressed on the following cable section with an attendant improvement in signal-to-noise performance. Balanced or unbalanced resistive terminations are also available if desired.

The physical arrangement of a video repeater is shown in Fig. 8. In this case a single repeater, cabinet-mounted for semipermanent use, is shown. In the central office three such repeaters are mounted on a standard 11-ft relay rack. A central office installation is shown in Fig. 9.

The Transmitting Terminal. Two versions of the video transmitting terminal are shown in Figs. 10a and 10b. The most commonly employed arrangement is given in Fig. 10a and consists essentially of a video repeating coil which permits coupling the usual 75-ohm unbalanced studio equipment to the balanced telephone cable, and a predistorting network which is employed when abnormally long cable circuits are involved. The repeating coil has a substantially flat transmission characteristic over the video band with the 3-db loss points at 30 cycles/sec and at about 8 mc. The physical arrangement of this type of video transmitting terminal is shown in Fig. 11.

In a few instances the first section of cable may be of considerable length. Here an amplifier may be employed as indicated in Fig. 10b. This amplifier is identical with the output type employed in the video repeater just described. The use of this alternative transmitting terminal permits the first cable section to extend to 3½ miles in length as compared with a maximum length of 1.7 miles when a repeating-coil type of transmitting terminal is employed.

Receiving Terminal. In Figs. 12a and 12b two alternative receiving terminal arrangements are shown, the choice

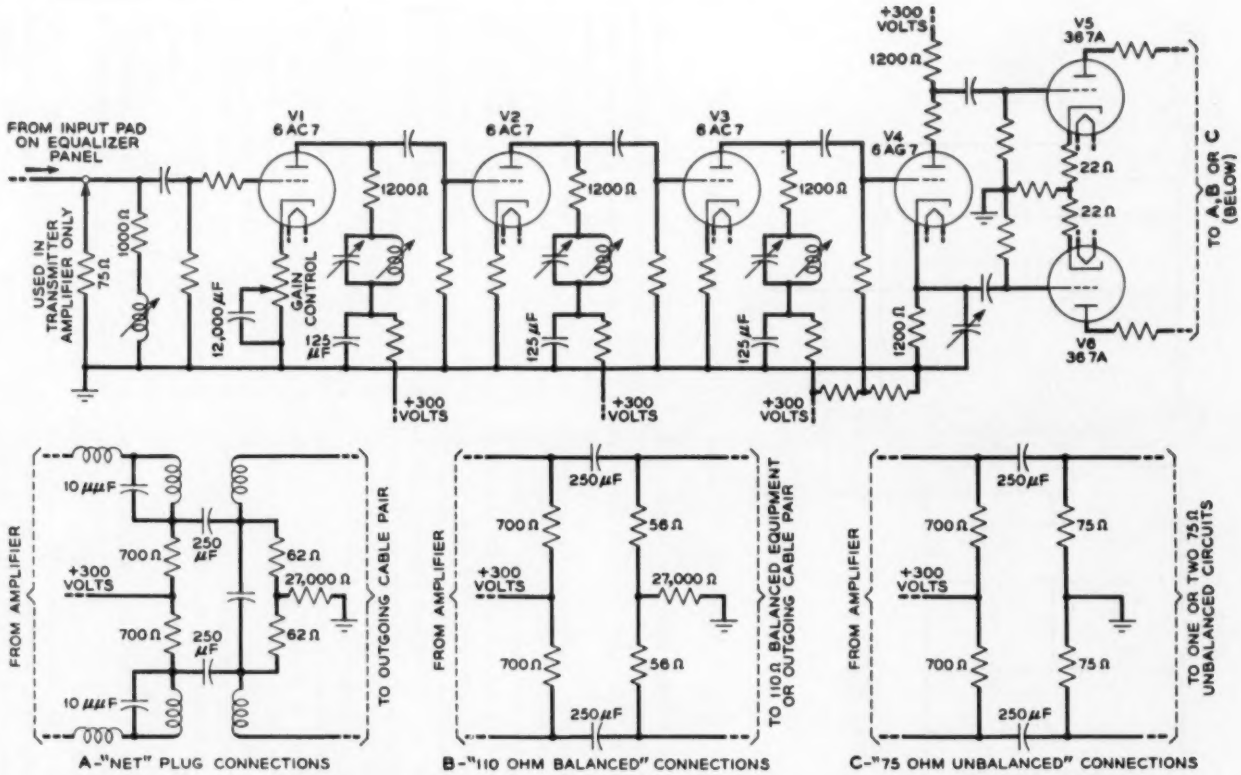


Fig. 7. Video repeater output amplifier—simplified schematic.

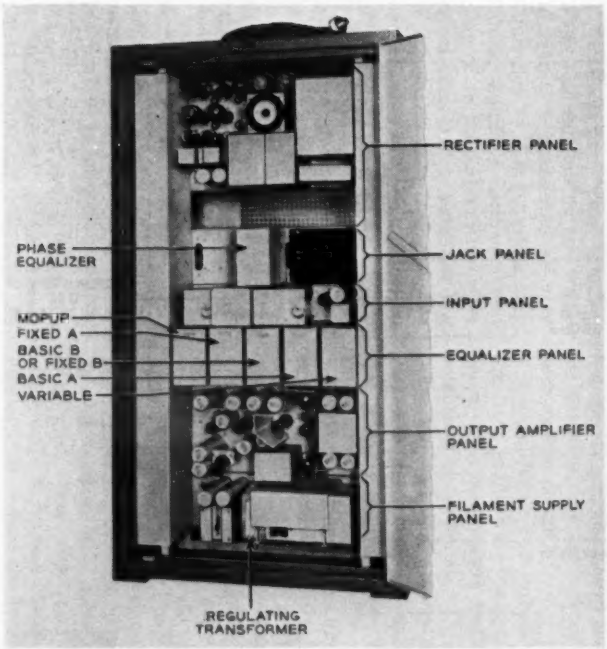


Fig. 8. Video repeater, cabinet-mounted.

Fig. 9. Installation of video repeaters in a telephone office.

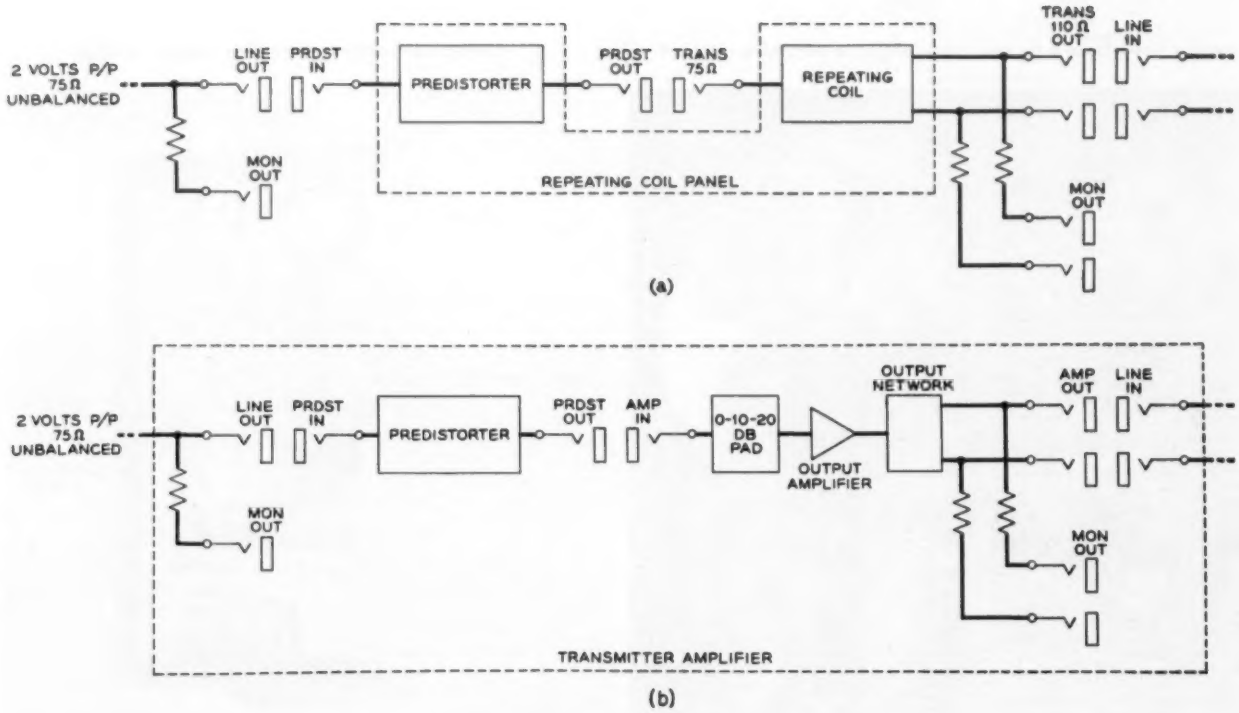


Fig. 10. Video transmitting terminals—block schematics.
(a) For cable sections up to 1.7 miles long; (b) For cable sections up to 3½ miles long.

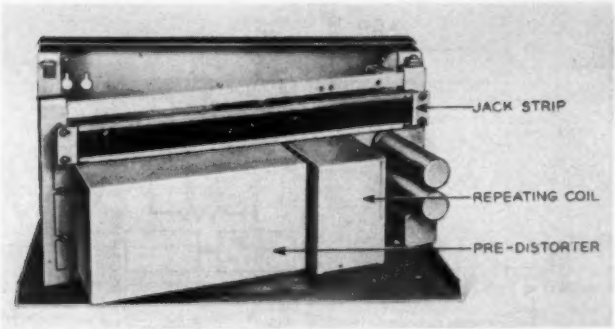


Fig. 11. Video transmitting terminal in wall-mounted bracket.

being primarily dependent on the loss of the final cable section. For shorter lengths of cable where the loss at 4 mc does not exceed 27 db, the arrangement of Fig. 12a is commonly employed. This terminal consists of a video repeating coil, a restorer network if required, and clamper amplifier. The clamper amplifier whose operation has been discussed elsewhere,[1] affords protection against low-frequency noise interference, as well as minimizing the transmission distortion introduced at very low frequencies by the repeating coil. The clamper amplifier here employed has a gain of 18 db and will furnish a 2-v peak-to-peak video signal into a 75-ohm impedance for use by the customer. It affords a 31-db reduction of 60-cycle interference.

If the final section of cable is greater than about 1½ miles, the receiving terminal arrangement shown in Fig. 12b is used. Here the basic components of the video repeater are employed and, if required, in addition a clamper amplifier is included as shown.

System Performance

The objective in the transmission and equipment design of the video system just described is to provide adequate transmission of video signals in local exchange areas with a minimum of cost. The final cost of such service is dependent only in part on the initial equipment and cable investment. The installation and maintenance charges contribute substantially to the over-all system cost. The ability to provide prompt and straightforward interconnections in the local area, regardless of the specific peculiarities of the particular situation, is a basic requirement of such system design.

The following two circuit examples are given to illustrate the application of these video components to the specific conditions encountered.

In Fig. 13 the transmission performance of a 2.78-mile circuit containing one repeater and simple terminals is given.

In Fig. 14 a longer and more complex example is presented. Here the total circuit length is 11.72 miles and is further complicated by the fact that one of the cable sections is 5 miles in length. This extreme condition is met here by transmitting the signal at a somewhat higher-than-normal amplitude over this section and also by operating the following repeater at somewhat increased gain. In this instance the noise conditions were such that this procedure was allowable. A mop-up equalizer is also employed to reduce the residual trans-

[1] S. Doba, Jr., and J. W. Rieke, "Clampers in video transmission," *AIEE Trans.*, vol. 69, Pt. 1, pp. 477–487, 1950.

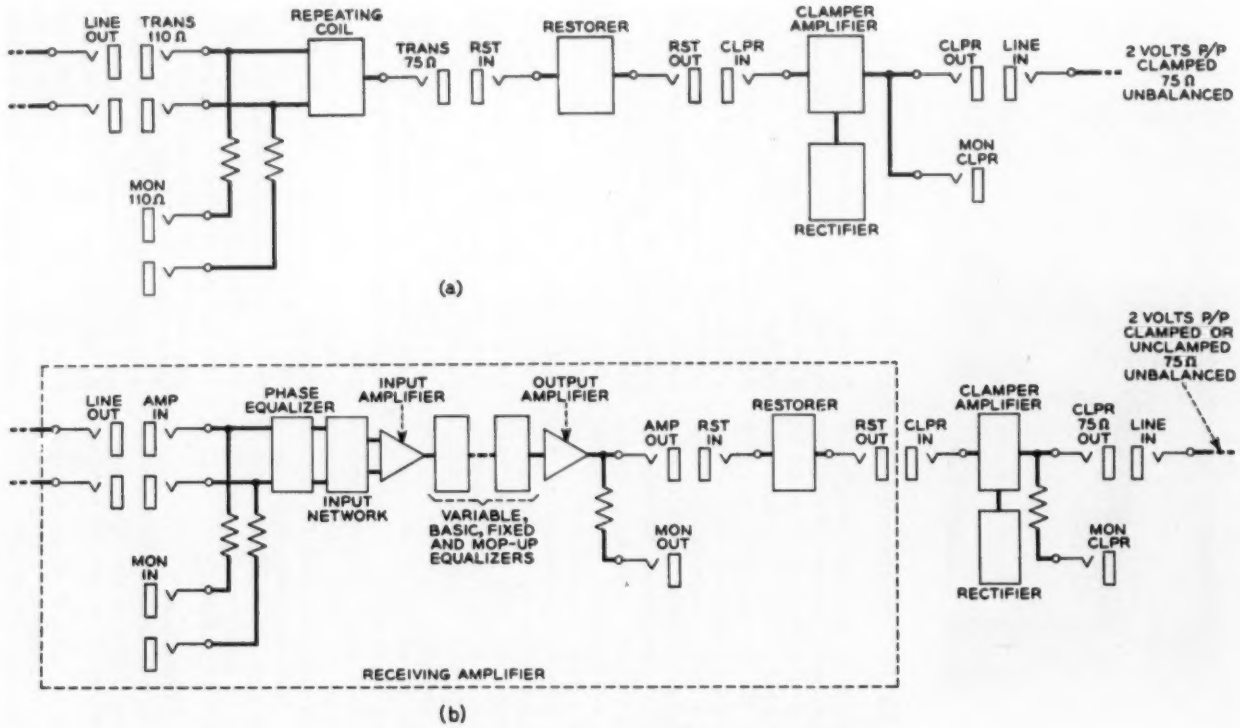
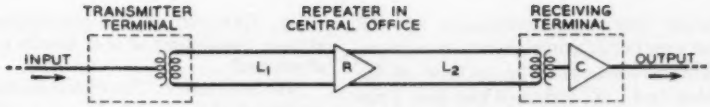


Fig. 12. Video receiving terminals—block schematics.
(a) For shorter lengths of cable; (b) For cable, final section of which is greater than 1½ miles long.



C = CLAMPER AMPLIFIER

CIRCUIT	MILES	4-MC LOSS IN DECIBELS
L_1	1.67	30
L_2	1.11	20
TOTAL	2.78	50

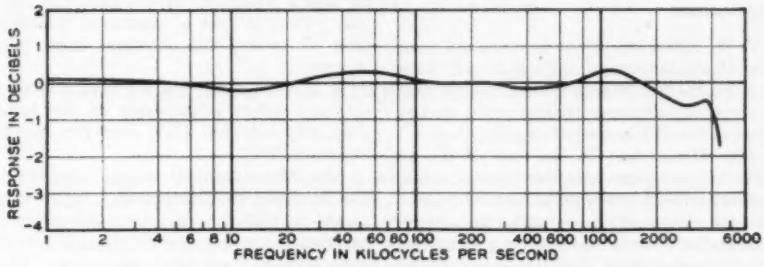
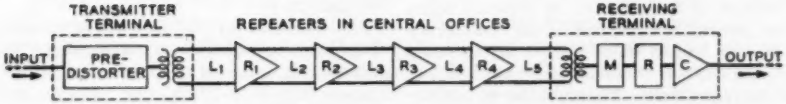


Fig. 13. Video circuit application—2.78-mile circuit.



M = MOPUP EQUALIZER
R = RESTORER
C = CLAMPER AMPLIFIER

CIRCUIT	MILES	4-MC LOSS IN DECIBELS
L_1	1.67	30
L_2	5.0	90
L_3	1.33	24
L_4	2.39	43
L_5	1.33	24
TOTAL	11.72	211

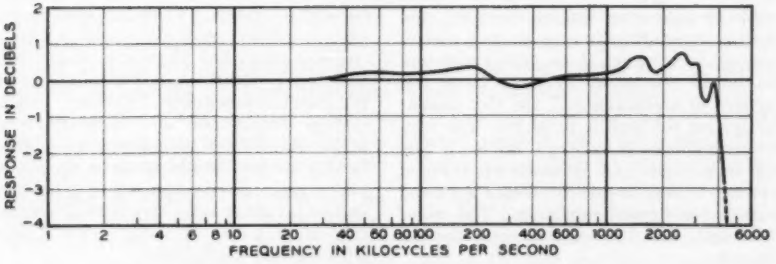


Fig. 14. Video circuit application—11.72-mile circuit.

mission distortion occasioned by the large number of components in tandem.

Acknowledgment. The author is indebted to C. N. Nebel of the Bell Telephone Laboratories for the illustrations used, as well as for the performance data for the two local video circuits discussed.

Discussion

E. W. KELLOGG: How does the attenuation characteristic of the cable you were showing in this picture compare with that of your long-distance coaxial cable, and to what is the difference principally due?

MR. MORRISON: In the case of the 16 PSV (polyethylene shielded video) cable, the characteristics are almost identical. As to attenuation versus frequency: essentially, the attenuation rises almost as the square root of the frequency in all these cables where we have no high dielectric loss in the region we are talking about. Now, in the case of the coaxial cable, we have polyethylene dielectric and here we have the same, so we do have the same form of characteristic. And as to the amount of attenuation, it depends upon the copper. In the case of the coaxial, we are able to put more copper in the same size of tube, if you will. The attenuation is lower per mile. The unbalanced characteristic of the coaxial, however, does not permit its use for video transmission over very long distances. The coaxial is not well shielded for low-frequency power interference. It has a steel tape, to be sure, as well as copper; but it is not adequate for television transmission. We are able to transmit video frequencies on balanced conductors in these places where we have high levels of interference; and that is generally the case in any metropolitan area where these cables are run. So, in the coaxial we limit the lower frequency of transmission. On the present LI system we limit it to 60 kc. For television we limit it to about 200 kc. The top frequencies can be made anything if you are willing to put in enough gain and narrow the repeater spacings. The wider the band, the closer the spacings for the amplifier.

DR. KELLOGG: Is the polyethylene dielectric continuous or is it merely a series of spacers?

MR. MORRISON: The dielectric does not occupy all of the space. It is not solid. In the coaxial system we use beads, at approximately 1-in. spacing, little discs of polyethylene; and in the case of this video cable which you saw, we used string spirally wound around it and tape over that, so that a good percentage of the volume is air. That is just a matter of handling, and of course the material itself costs money.

H. J. SCHLAFLY: Do you find that there are any other advantages of the longitudinally shielded PSV over the spirally shielded PSV?

MR. MORRISON: It is just a matter of the shielding that we obtain. Whereas we might get 120 db on one type as a reference number, we might get 20 db more on the longitudinally shielded conductor. It is just a matter of making a good tight copper shield around the conductor. The present manufacture is longitudinally seamed plus a winding as you saw in the second figure—a spiral tape of copper. It is shielding to external fields. That is all we gain by it.

E. A. HUNGERFORD, JR.: I was wondering if you could tell us anything about the possible demand for r-f distribution of television signals to advertising agencies and so on in New York City where you could get away from going through the air. Has the company had a requirement for that yet?

MR. MORRISON: There are always a certain number of requirements for experimental purposes that come in at the front or the back door. All though this, people are interested in point-to-point connections of television. There has been no real rush to connect up the city with a form of entertainment like Muzak in sound [distribution]. However, it is certainly within the realm of possibility, I believe; and for certain commercial and industrial purposes, the ability to connect up a video facility as you would connect up a telephone may prove to be rather attractive. But so far there is no commercial application of that sort of thing, none at least with which I am familiar.

A Professional Magnetic-Recording System for Use With 35-, 17½- and 16-Mm Films

By G. R. Crane, J. G. Frayne and E. W. Templin

This paper describes a portable magnetic-recording system for producing high-quality sound track in synchronism with pictures. The system has been designed to enable magnetic recording to conform with standard motion picture studio operating practices. A number of features such as high-speed rewind, interlocked-switching facilities, one basic type of amplifier and the use of miniature tubes throughout have been incorporated in the system.

THE MAGNETIC-RECORDING SYSTEM described in this paper is an evolutionary development of the application of magnetic-recording techniques for motion picture purposes. In previous papers presented before the Society,[1,2] complete descriptions have been given of the various supplemental magnetic-recording facilities which have been made available to the motion picture industry by Western Electric Company and the Westrex Corporation. The widespread use of these modified photographic recorders has provided an unusual opportunity to evaluate the performance under actual field conditions of the various circuits and mechanical devices incorporated in these modifications. In the design, therefore, of this completely new magnetic-recording system, those elements have been retained that have proved to be of definite value, while others that have proved superfluous have been eliminated.

It was stipulated that the new magnetic-recording system should be capable of being operated with any of the known motor systems commonly employed in the motion picture industry. These include single-phase and three-phase synchronous, a-c and d-c interlock, as well as multiduty operation.[3] The motor-control circuits of the recorder should be arranged so that in order to change from any one motor to another, it is only necessary to disconnect and remove the motor, replace it with the other type and reconnect it with a minimum of effort.

Before establishing a suitable sound-track position for this system, it was decided to adhere to what may become an industry-wide accepted standard. To this end, there has been active cooperation with the Motion Picture Research Council and the Magnetic Subcommittee of the SMPTE to try to

Presented on October 18, 1950, at the Society's Convention at Lake Placid, N.Y., by G. R. Crane, J. G. Frayne and E. W. Templin, Westrex Corp., 6601 Romaine St., Hollywood 38, Calif.

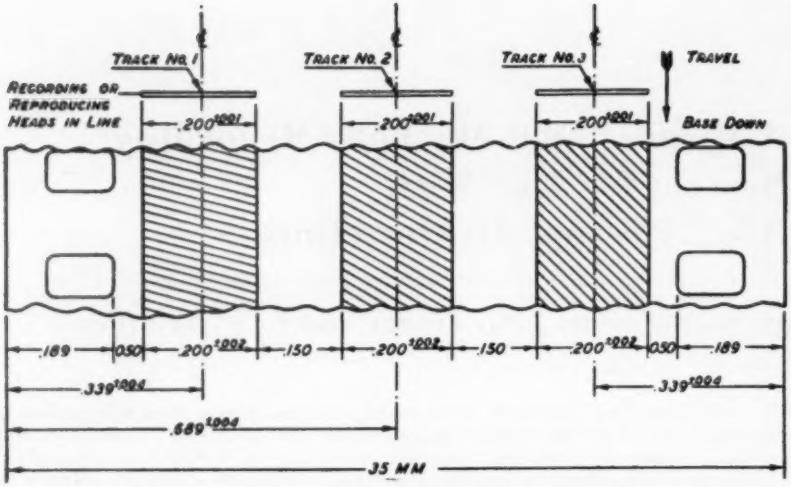


Fig. 1. Proposed magnetic film-track standards.

establish a single- and multiple-track standard for 35-, 17½- and 16-mm films. Unfortunately, the proposals of both of these organizations have not yet reached the stage of complete standardization, but the response of the great majority of equipment manufacturers and recording studios has been so favorable that it was decided to proceed on the assumption that they would eventually be accepted as standard.

The American Standards Association and the Research Council track proposal is shown in Fig. 1. It provides for three 200-mil tracks, with a separation of 150 mils between tracks and a 50-mil separation between outer tracks and sprocket holes. Track No. 1 on the left of the figure becomes the normal single track, and it will be noted that it is the so-called negative sound-track position. It differs from the original track location previously described in that it has been moved in from the 136-mil separation from the sprocket-hole side to the present 50 mils. This was done to permit the later development of multitrack recording in accordance with Fig. 1. It should be noted that although the recorder described below is designed to meet the new proposed track standard, provisions are incorporated for restoring the older track location when desired.

The situation with regard to 17½-mm film track standards is not as clear as with 35-mm film track. The original proposal was to record down the slit edge of this film. This would correspond to a positive sound-track position for this film. A later proposal called for the 17½-mm track to be in an identical position with that of the 35-mm film. In the recorder described below, provision has been made to record the 17½-mm track at either of these positions, and experience alone can tell which is more likely to be adopted on an industry-wide basis.

The track position for 16-mm film has been set at 6 mils from the unperforated edge and no request has been made so far for any variation from this position. In all three cases, the track width is 200 mils and the same recording head is used for all three positions.

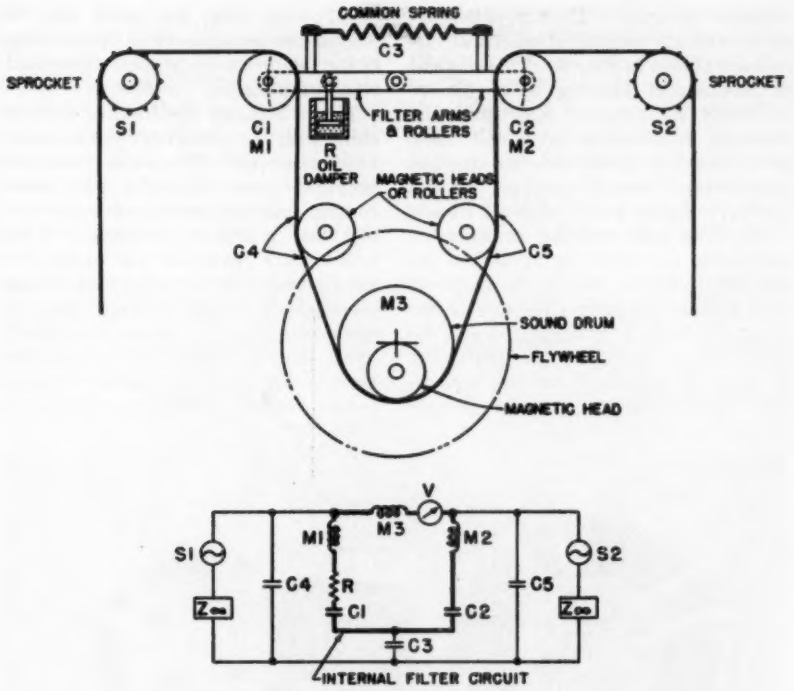


Fig. 2. Film-drive schematic.

It was decided that provision for high-speed film runback should be available in this system. This was considered a necessity in the foreign field and a desirable accessory in the domestic field. An actual runback speed of 3× has been provided in the system described in this paper. As will be seen later, this is accomplished without unthreading the film in the recorder.

Recorder

The recording machine has been designed primarily for portable use as a production recorder for magnetic sound in synchronism with a motion picture. The machine and its control features are readily adaptable to any of the current types of motor-drive systems including interlock, multiduty and synchronous, either 1 ϕ, 115 v or 3 ϕ, 220 v. In addition, it may be readily equipped for operation with 35-, 17½- or 16-mm film which changes only a few parts of the recorder, such as rollers, sprockets and reel shafts.

Recorder Film Path

The film drive is of the Davis type, which was discussed in an earlier paper published in the JOURNAL,[4] and consists of two 16-tooth sprockets with a symmetrical, tensioned path between them, which includes two filter rollers and an impedance drum within which is located the record head. The path also includes a slight wrap around a monitor magnetic head beyond the drum, and a roller which may be replaced by an optional erase head just

ahead of the drum. The film-path schematic and its equivalent electrical circuit are shown in Fig. 2. This method of mechanical filtering is, of course, in effect a low-pass filter and the damping is provided by an oil dashpot connected to one arm to give approximately critical damping at its natural resonant period of about 1.6 sec.

The film path and its elements are essentially the same for 17½- and 16-mm film. In the case of the narrower film widths, the lateral position of the magnetic heads is not changed and the roller flanges are placed so that the film is properly registered with the heads for correct track position. In the case of 17½-mm film, the track may be recorded either adjacent to the split edge of the film or in the Academy proposed-standard position.

Figure 3 shows the front of the machine with the cover over the magnetic heads removed. Two shock rollers are provided over which the film passes coming into the feed sprocket and leaving the holdback sprocket. These rollers have relatively low inertia and are controlled by a spring and a single oil dashpot. They protect the film sprocket holes from abuse, particularly when the machine is started or when there is any abnormal operation such as jerks or erratic motion imparted to the

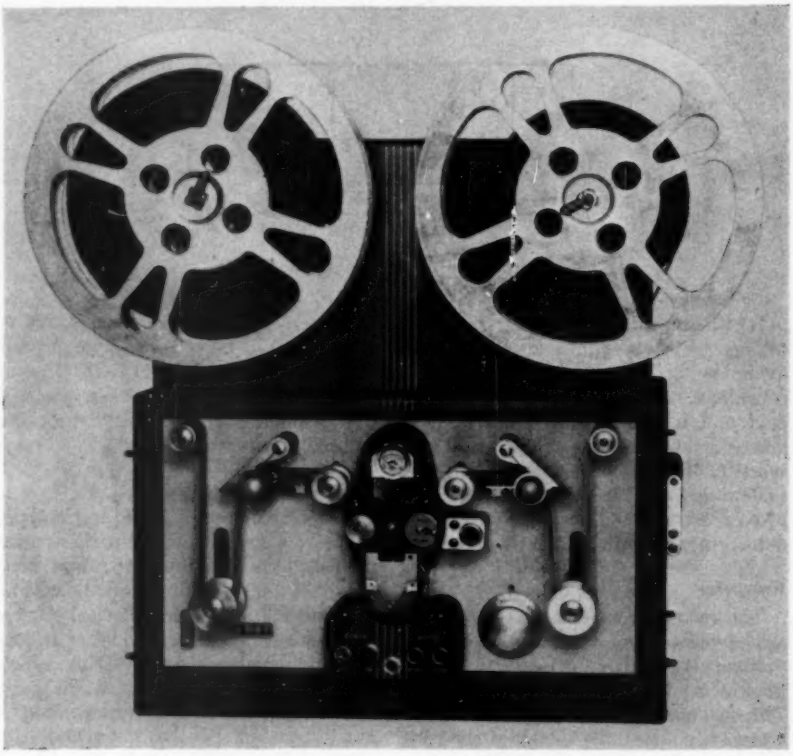


Fig. 3. Front view of RA-1467 Recorder with cover of head assembly removed.

film by imperfect reels. The right-hand shock roller serves also as an "antibuckle" device or indicator of loss of take-up tension. The details of this function will be described later.

The film sprockets have relatively large teeth which fit rather closely into the sprocket holes and take advantage of the low-shrinkage characteristics of the new acetate-base film. The tooth clearance in the hole is still sufficient to permit satisfactory operation with moderately shrunk film as high as 0.6%, but the clearance is small enough to eliminate most of the so-called crossover effect caused by the changing film tensions on the two sides of the sprocket causing the sprocket to act alternately as a feed and holdback sprocket. Both sprockets have flanges as an aid to rapid

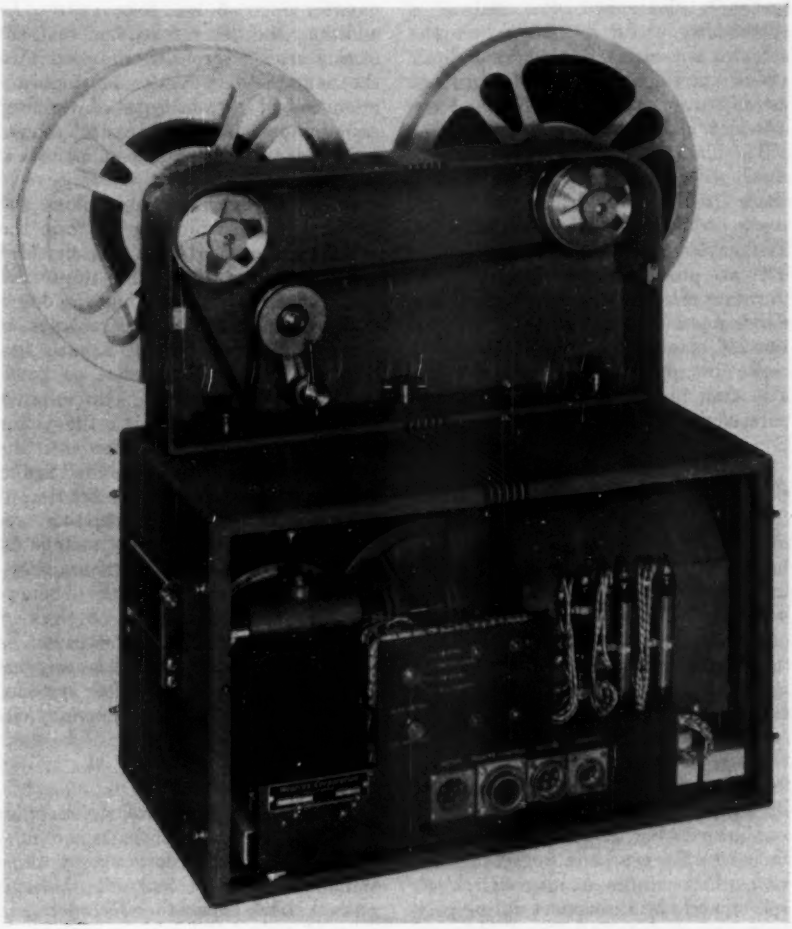


Fig. 4. Rear view of RA-1467 Recorder.

threading and this has permitted the use of a simple film shoe instead of the usual sprocket pad-roller assembly. This shoe is adjusted so that it clears the film surface during normal operation. It serves only as a guard for such conditions as starting and stopping the equipment. Each sprocket also has a knob by which the machine may be turned over when the selector knob is in the "Neutral" position. Since the motor is disengaged, this feature is particularly useful in cases where the machine is used as a dubbing reproducer and a start mark must be registered without disturbing the position of the interlock motor.

The film passes in and out of the machine to reels located above, with a single, round belt driving both reel shafts, which may be seen in Fig. 4. Convertible overrunning-clutch assemblies are provided to permit either reel to rotate in either direction to meet the varying practices with regard to direction of rotation of feed and take-up reels now prevalent in the industry. The same belt may be used with alternate crossed paths to change the rotation.

Recorder Controls

The motor is controlled by a d-c relay of the mechanical-latch type with push buttons for start and stop. This system has the double advantage of having no power in the relay during operation of the machine, thereby simplifying the magnetic shielding problem and providing a convenient method for controlling the recorder remotely with momentary-contact switches carrying only relay-coil current.

The machine functions are controlled by a single selector knob on the front, as shown in Fig. 3. It is mechanically linked to the gear box for speed selection. It operates a microswitch for speech and bias disconnect during playback and rewind, and also disables the antibuckle device during rewind. Erase facilities are controlled in a similar manner if used.

The shock roller which is used for indication of take-up failure occupies the same position at rest and at take-up failure; therefore, the operating circuit is not energized until 3 sec after start. A time-delay relay across the motor circuit performs this function as well as operating the relay to transfer the recordist's monitor from direct to film monitor after 3 sec from start. In addition, the delay relay has contacts closing after 1 sec to short resistors in the motor line to reduce the high acceleration of certain types of synchronous motors. All relays are, of course, reset instantaneously when power is removed.

In the event of take-up failure, the motor is lifted from the line and the main transmission circuit is disabled which removes the signal from the mixer's volume indicator and the direct monitor line. Since the recorder is stopped, film monitoring is also terminated. The buckle condition is restored only by operation of the recorder power switch to "Off," but the motor is not reconnected to the line until the motor "Start" button is operated again.

To provide the proper correlation of the synchronous-motor starting resistors, the time-delay relay voltage requirements, and other circuit functions, a four-position switch with a screwdriver-slot control appears on the rear panel of the recorder. This switch is set to the indicated position for any one of the various types of motor systems, thereby making all of the necessary circuit changes.

Recorder Structure

The upper assembly of the recorder containing the two reel shafts is removable from the recorder case by three thumbscrews. The take-up belt is pushed back into the recorder and covered with a sliding cover. Space is provided in the control unit for contain-

ing the reel assembly when the system is to be transported. The recorder case has a removable rear cover for access to the motor-starting resistors and other components, and contains a recessed opening through which all of the cords may be inserted into the recorder receptacles. A front cover with a transparent window is used primarily for a dust cover during stand-by or for shipment. It is also useful in those cases where the recorder is to be operated near the action, thereby requiring further reduction of recorder noise and that caused by the film engagement on the sprockets. An accessory magazine is also available for completely enclosing the two film reels for further reduction of noise caused by film scuffing on reel flanges. This magazine is demountable and has transparent doors for visibility.

Mechanical Drive

As previously mentioned, various types of motors may be accommodated and the one selected is directly coupled through a torsionally rigid, flexible coupling to a gear box.

Between the gear-box output shaft and a cross shaft, interchangeable sets of 90° helical-change gears are used to accommodate all currently used motor speeds from 1000 to 1800 rpm for either 35-mm or 16-mm film speeds. The cross shaft drives each of the two sprocket shafts through similar 90° helical gears. Each of these three sets of gears has a nylon plastic gear driven from a steel gear which gives quiet and smooth operation. Nylon was chosen as the nonmetallic material since it has unusual properties suitable to this application. It is capable of running with virtually no lubrication and performs very well over long periods of time with a minimum of lubrication provided by a drop or two of a special oil which clings to the tooth surfaces with high tenacity. The material is extremely tough and accepts considerable abuse in shock loading without damage.

The gear box accomplishes a 3:1 speed change by means of planetary gears and the ratio change is accomplished by a spring-loaded control rod protruding from the center of the driven shaft.

The take-up clutches associated with each reel shaft contain overrunning clutches as well as a frictional drag to the frame of the machine, so that no attention need be given to the take-up performance regardless of the direction or speed of the recorder. The take-up clutch provides the proper film take-up tension on the reel which requires it, and a second small clutch places a light drag on the feed-reel shaft to insure stable operation.

The impedance drum, the two sprocket-shaft assemblies and the pad-roller assemblies have their ball bearings contained in tubular subassemblies so that their lateral position may be easily adjusted and locked by means of set screws. All rollers have their shafts arranged so that they may be likewise adjusted laterally. These facilities permit changes and alignment adjustments in film-path components to be readily made with a minimum of effort. Until track positions are more universally standardized and accepted, this feature may be useful.

The head assembly containing the two magnetic heads, or three in the case of the erase option, may be removed as a complete unit and replaced on dowel pins without disturbing any of the head adjustments relative to the impedance drum. The wiring between the magnetic heads and the recorder is terminated through a small symmetrical seven-pin plug arranged to permit a 180° turnover. This reverses record and moniter connections so that the monitor head may be used in the rare event of failure at the record-head position or the record head may be used for high-quality reproduction as in the case of transfer machines or high-quality playback. The record and monitor

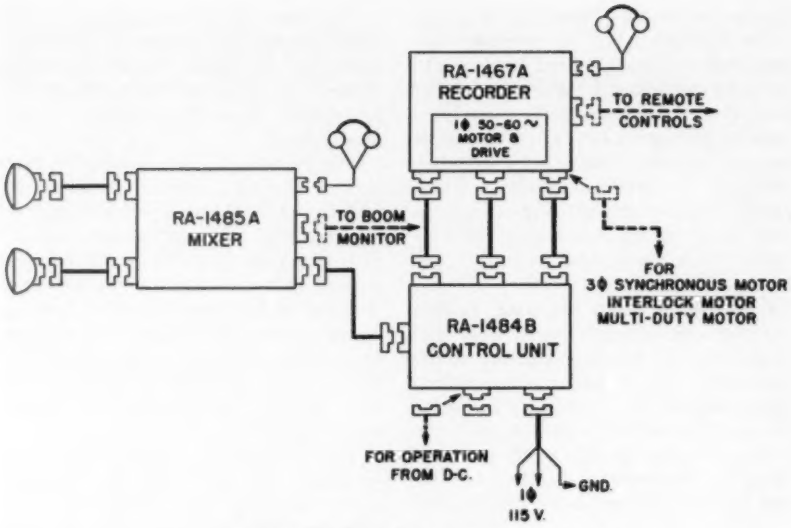


Fig. 5. System block schematic.

heads have mountings equipped with vernier-screw adjustments for setting azimuth quickly and accurately, and the solidly mounted record head has a vernier adjustment for its position relative to the impedance drum and the film. The head curvature lying within the film curvature determined by the impedance drum insures excellent contact with the magnetic coating and its position is such as to insure a long period of service without requiring any readjustment for wear compensations.

Transmission System

An over-all block schematic of the system is shown in Fig. 5. The three basic units are shown: the Recorder, the Mixer and the Control Unit. The control unit is normally associated closely with the recorder and connected to it by two 10-ft interconnecting cables. The motor cable also connects directly between the recorder and control unit when a 115-v, 1-ϕ drive motor is used. Only one interconnecting cable is required between the mixer and the control unit. The separation between these units may be 50, 100 or 150 ft with no special provisions required for normal variations in power-supply voltage and voltage drop in the interconnecting cable. An additional cable from recorder to studio facilities may be used to provide motor start-stop controls, speed signal and footage-counter control at remote points.

The transmission system is built up of combinations of three basic types of electronic subassembly components: an amplifier, an oscillator and a power supply. This method of building up the system from a minimum number of standardized types of subassemblies has several advantages, including economy of manufacture, simplicity of maintenance and a minimum investment in studio plant and location spares.

Amplifier

Only one type of amplifier is used throughout the recording system. A total of four are used in the system, one each for the two microphone preampli-

fiers, one for the main recording amplifier and one for film monitor. Only one type of vacuum tube is used in all the amplifier applications—the G.E. 12AY7 miniature twin triode. The special performance requirements for the particular amplifier applications are all accommodated by a series of plug-in units which make connections to internal circuits of the amplifier.

With suitably filtered power supply for plates and heaters and with a reasonable amount of selection of tubes for the input stage, a noise level of approximately −125 dbm, referred to the amplifier input, may be obtained. This permits a signal-to-noise ratio of approximately 55 db for normal dialogue pickup from a W.E. RA-1142 Microphone.

The amplifier will carry an output power level of +22 dbm for 1% distortion which provides a comfortable margin over that required for both recording and monitoring applications.

The power requirements are 10 ma (milliamperes) at 275 v d-c and 0.3 amp at 12 v. A d-c or rectified a-c heater supply is recommended for all low-level applications.

Bias Oscillator

The oscillator is of the L-C tuned-grid type, operating at 60 kc and employing one 12AU7 twin triode operating in push-pull. The total distortion appearing at the oscillator output terminals is less than $\frac{1}{10}$ of 1%. The oscillator will deliver at least 35 ma at 60 kc into the record head. The power requirements are 6 ma at 275 v d-c and 0.15 amp at 12 v a-c or d-c.

Power Supply

The power supply provides line-and-load-regulated plate current and unregulated heater current for the entire system. It requires 1 amp from a 50- or 60-cycle 115-v power source.

The circuit includes a 3-stage d-c amplifier and a series regulating tube. Regulation over a line-voltage range of ±10% and a load range of 0 to 55 ma is obtained with a maximum of not more than 0.5 v variation in output. The total power-supply ripple is approximately 0.5 mv or less over the complete load range. The a-c impedance of the output is also held to a very low value, thus simplifying the decoupling requirements between stages of an individual amplifier as well as between high- and low-level amplifiers. The output voltage is adjustable over a range of 255 to 300 v but is normally intended to be set to 275 v.

A bridge-type selenium-cell rectifier is used to provide 12 v d-c for vacuum-tube heater and relay control circuits. This supply is biased 20 v above ground which makes the vacuum tubes in low-level stages less sensitive to residual power-frequency ripple and simplifies the filtering requirements. This supply provides 1.8 amp at 12 v with a ripple less than 1 v. For a ±10% variation in power-supply voltage and for mixer cable lengths up to more than 100 ft. the voltage at the heaters is within safe operating limits without special regulating or current-limiting provisions.

Mixer

The mixer is a complete speech-input equipment having two microphone inputs and supplying signal directly to the recording head, direct-monitor lines and volume indicator. Figure 6 is a view of the mixer.

Three of the basic amplifiers previously described are used in the mixer, two as microphone preamplifiers and one as the recording amplifier.

For the preamplifier application, the plug-in unit inserts variable dialogue equalization and low-frequency pre-equalization. The dialogue-equalizer characteristic is selected by a control knob on the top of the plug-in unit. The response curves are shown in Fig. 7. One position provides the normal flat amplifier characteristic; the other two provide, respectively, 8- or 12-db droop

at 100 c(cyles per sec). These characteristics follow the conventional ones that have been used for many years in Hollywood studios. Below the useful dialogue range they maintain sufficient loss so that a high-pass filter is not normally required. This is particularly the case since the low-frequency difficulties in photographic recording attributable to noise-reduction and peak-limiting operations are inherently absent.

The low-frequency pre- and post-equalization used in the system takes advantage of the energy-distribution characteristic of speech and music[5] to increase the margin between signal and residual-hum components in the reproducing or monitor system. As shown in Fig. 7, the pre-equalization amounts to a 2½-db rise at 50 c.

The design of the equalizers is such that the gain in the region of 1000 c is essentially unchanged for all settings of the dialogue equalizer and with the low-frequency pre-equalizer in or out of circuit.

The plug-in unit also contains resistive elements which introduce attenuation in the amplifier circuits terminating therein. The gain of each stage is thereby carefully established at the value giving the best possible balance between signal-to-noise and margin-from-overload, based on the sensitivity of the microphone and the range of input level to be accommodated. The midfrequency gain of the amplifier as

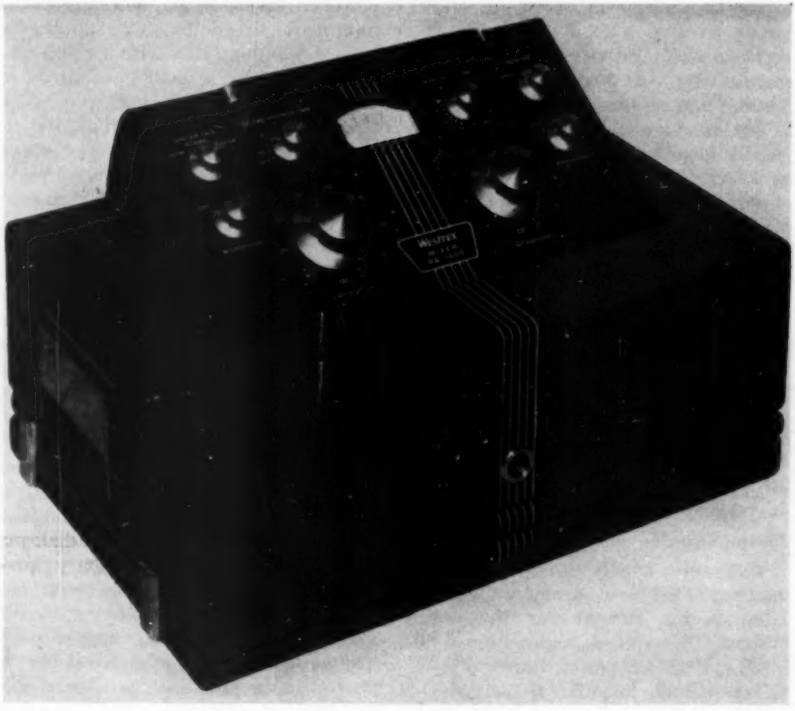


Fig. 6. View of RA-1485-A Mixer.

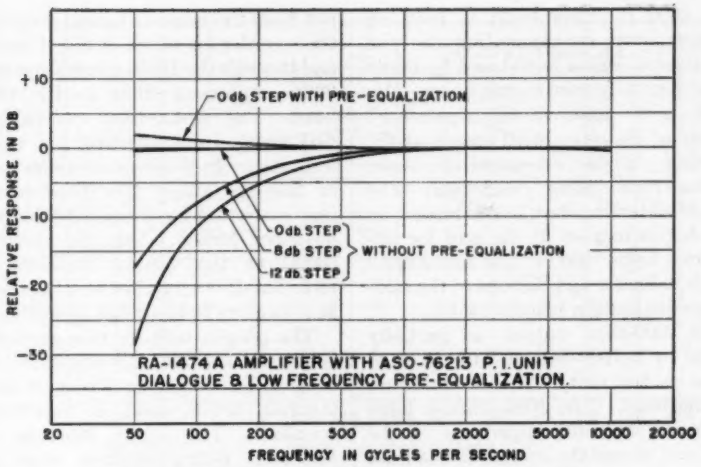


Fig. 7. Preamplifier gain-frequency characteristics.

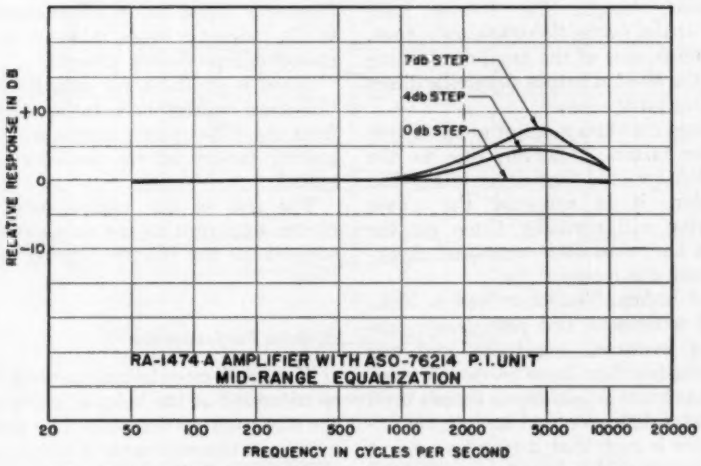


Fig. 8. Recording-amplifier gain-frequency characteristics.

established by the plug-in unit is 53 db.

The preamplifiers are followed by separate microphone cutoff keys, mixer pots, a combining network and a gain switch having three 10-db steps.

Following this is the recording amplifier with its input connected for unbalanced, 600-ohm, terminated operation. The plug-in unit in this application provides two steps of midrange equalization in addition to the flat characteristic, a choice of the three conditions being selected by the control knob in the top. As shown in Fig. 8, this equalization consists of a rather broad peak of either 4 or 7 db centered

near 5000 c. This boost is used on dialogue only, supplementing the rise in this same region introduced by many of the regularly used microphones. Its result is to improve the "presence" quality of the reproduced speech at the listening levels encountered under theater reproducing conditions. The gain of this amplifier is established in the plug-in unit at 58 db, and for frequencies below 1000 c it is maintained at this value for all positions of the mid-range-equalization control switch.

The 600-ohm output is partially loaded by a 1000-ohm resistor (located in the control unit) which feeds the recording head. The 1000 ohms is large compared with the impedance of the head and causes the current in the head to be substantially independent of the head impedance throughout the audible frequency range. The volume indicator is also across this 600-ohm output. The remainder of the amplifier loading is on the 50-ohm output supplying direct monitor for the mixer.

Direct and film monitor are available in the mixer. However, due to the fractional-second time delay in the film monitor, it is expected the mixer operator will normally listen on the direct line, with only occasional checking from the recorded film.

The volume indicator has a high-speed movement and new design providing increased sensitivity and less bridging loss than those previously used. Its maximum sensitivity is 0 dbm for 0 db meter deflection and its internal impedance is such that it may be used at this setting under operating conditions.

Control Unit

The control unit contains miscellaneous components including the bias oscillator, film-monitor amplifier, power supply and interconnecting circuits between the mixer and the recorder. It also provides storage space for the film-reel assembly which mounts on the recorder during operations. The output from the mixer is carried directly to the recorder for recordist direct monitor and through the 1000-ohm resistor and a 60-kc suppressor filter to the record head. The 60-kc filter prevents the bias signal from affecting the volume indicator. In the event of a film buckle or take-up failure, this direct-monitor line is shorted by the antibuckle relay described earlier. This also shorts the signal to the volume indicator and recordist direct monitor and thus serves as a warning to the mixer operator.

The plug-in unit for this application contains a continuously adjustable gain control, for balancing film and direct-monitor levels, and a reproducing equalizer. The latter has the conventional 6-db-per-octave slope plus low-frequency postequalization complementary to the pre-equalizer, and high-frequency equalization complementary to the magnetic losses inherent in the recording-reproducing process.

Space is available for substituting a bias-erase oscillator operating directly from the 115-v power source when the erasing facility at the recorder is required.

The size of the control unit was chosen to permit its use as a mounting support for the recorder during operations.

System Performance

The 100%-modulation recording level, as measured at the volume indicator in the mixer unit, is determined by making a series of measurements of output level and per cent distortion at the reproducing-amplifier output for various values of recording level and bias current. A typical set of data for a particular recording head and film emulsion is shown in Fig. 9. Based on an allowable total harmonic distortion of 3%, it can be deduced from the curves that a 100% modulation recording level of +10 dbm, with a bias current of approximately 25 ma, is optimum. Lower

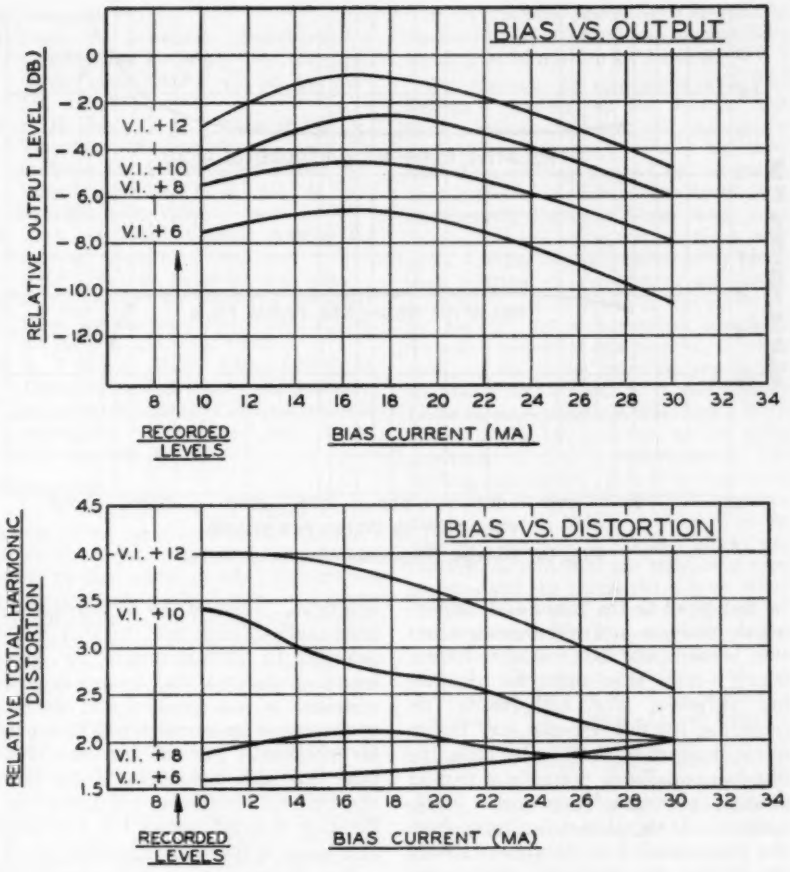


Fig. 9. Magnetic-recording characteristics.

recording levels give a lower reproducing level with corresponding decrease in signal-to-noise ratio. Higher recording levels require increased bias current for the permissible amount of distortion, with no appreciable increase in output level. For this optimum operating condition, a level of −4 dbm is available at the recorder on either direct or film monitor.

By means of the mixer pots and main gain control, a 60-db range of input level may be held to the 100% modulation level of the system. For any combination of mixer and gain settings, the carrying capacity will be limited by the film medium rather than by the transmission equipment.

The signal-to-noise ratio of the recording circuit as limited by the first stage of the preamplifier is approximately 55 db for normal dialogue.

The over-all record-reproduce film characteristic for 35- or 17½-mm films,

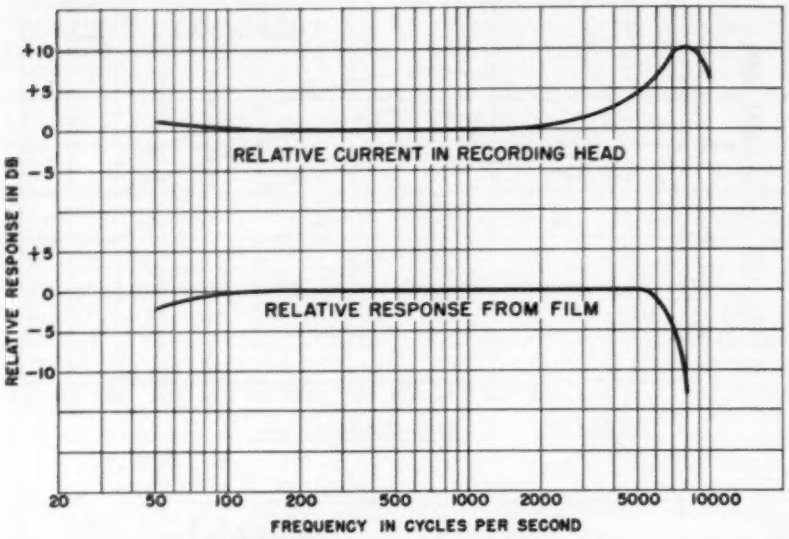


Fig. 10. 16-mm frequency characteristics.

for flat input to the mixer and, excluding the dialogue and midrange equalization, is essentially flat from 50 to 7000 c, which is more than ample for monitoring purposes. For high-quality re-recording, the flat response may be extended upward to 10,000 c by using the film-loss equalizers, normally a part of existing photographic-magnetic re-recorders. A signal-to-noise ratio from the reproduced film of approximately 55 db may be obtained. For special applications, this may be increased to 60 db or more as has been done in earlier photographic-magnetic equipment[1] by additional low- and high-frequency pre- and post-equalization.

Where high-frequency pre-equalization is to be utilized for this further increase in signal-to-noise ratio, an appreciable portion of it can be considered as precompensation for the magnetic and scanning losses inherent in the recording-reproducing process. These latter losses then introduce the compensating post-equalization to provide the flat over-all record-reproduce characteristic. Thus, if the high-frequency pre-equalization is held to that value required to precompensate for these losses, an electrical high-frequency post-equalizer is not required and flat response up to approximately 9000 c may be obtained. For 35-mm or 17½-mm film, this pre-emphasis has been obtained by a condenser-resistance combination shunted across the 1000-ohm resistance in the recording-head circuit.

For 16-mm film, with its inherently lower cutoff frequency, a series-tuned circuit is bridged across the resistor in series with the head to provide a high-frequency pre-equalization characteristic as shown in Fig. 10. A typical gain-frequency response from film recorded with this characteristic and reproduced on a high-quality re-recorder is also shown in Fig. 10. The response is substantially flat to approximately 6500 c, except for the low end which contains reproducing post-equalization to compensate for the low-end pre-equalization generally used in Western Electric magnetic recording systems.[1]

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Discussion

E. W. KELLOGG: With regard to the Davis Drive mentioned in the paper, I don't know just what it is intended to cover by that name, or what features are to be credited to Mr. Davis. I wish to call attention to the fact that if, broadly, the filter system means a solid flywheel on the shaft of a drum, and compliance introduced between the driving sprockets and the drum by means of a flexibly mounted idler-roller, that system dates back to ancient history. It was shown in a Triergon patent filed in the United States in 1922. It was again shown in slightly more definite form in a patent to Poulsen and Petersen, under which an unsuccessful infringement suit was brought against RCA Mfg. Co. and Electrical Research Products, in the late 1930's. It is a very effective filter, and I think all fundamental patents on it have long since run out. The feature of connecting a dash-pot to the movable idler is described in a 1931 paper of mine, describing the first RCA magnetic-drive recorder and also in the corresponding patent, in which broad claims were allowed on damping. I think that we should, in attaching anyone's name to a filter system, make it clear that it does not comprise those broad features that I have just described. Perhaps you can enlighten us about the features that have been added in the way of refinements or improvements.

In the machine just described, what is the position of the recording or reproducing magnet in relation to the drum?

DR. FRAYNE: In connection with Dr. Kellogg's question, all the data on the track width and location will be found in the published paper. I would say this, that the recording part of the magnetic head is placed as close to the drum as is mechanically feasible. Under those conditions we have no trouble whatever with quick starting of the drum or other problems relating to velocity or amplitude modulation. The flutter in this machine, by the as yet nonaccepted standard, measures somewhat less than $\frac{1}{10}$ of 1 per cent and the flutter rates are practically all above 100 cycles, as is customarily found in most magnetic recorders. With regard to the Davis Drive, we are quite cognizant of the contributions of Dr. Kellogg and others. It is to be regretted, however, that they never saw fit to introduce it to the industry. The Western Electric Company, as far as I know, was the first to introduce the tight-loop type of drive and the Davis Drive is so called for the reason that it was recognized by the Academy and given an award; and in that award, the name "Davis Drive" was created. The name "Davis" was not given to the drive by the Western Electric Company. The Davis Drive itself is covered by a U.S. patent, the principal patentable feature being the common spring connecting the two compliant rollers. The tight loop thus created eliminates the necessity of the customary pressure-pad roller. Shortly after we introduced this tight-loop drive, our competitors brought out a similar one. Perhaps Dr. Kellogg could enlighten us on why that happened.

DR. KELLOGG: Dr. Frayne has brought up the matter of the introduction to the industry of the filtering system which depends on damped movable idler-rollers. Certain obstacles to the use of this system were cleared away in the early 1940's, but the war years were not the time to jump to new models, particularly when the older ones were doing well, which was certainly true of the RCA rotary stabilizer soundheads. But our first postwar recorders, and 16-mm projectors, utilized filters of the damped, movable-idler type.

Carbon Arc Characteristics That Determine Motion Picture Screen Light

By M. T. Jones and F. T. Bowditch

In a carbon arc motion picture projector, definite relations exist between screen light on the one hand, and the arc current, current density, carbon size and the speed and collection angle of the projector optical system on the other. Measurements on more than 100 standard and experimental carbon arcs, with carbons ranging in size from 9 mm to 16 mm, have provided data to establish these relationships. Conditions are defined which are of importance in the matching of an optical system to a given arc, or vice versa, and for obtaining optimum performance in any situation involving screen distribution, amount of light and preferred current.

IN AN EARLIER PAPER[1] a method is described for calculating motion picture screen light from measurements of brightness over the carbon arc crater as viewed from selected angles, and from a consideration of the characteristics of the particular optical system involved. This method has now been applied to a variety of standard and experimental carbons, and the resulting data analyzed to establish certain significant relationships which form the subject of this paper. These relationships are concerned with the distribution and the amount of light delivered to the motion picture screen, as these are determined by the arc current, the current density, the size of carbon and the collection angle and speed of the optical system.

As an illustration of the basic data from which these trends are established, calculations made from measurements on three experimental trims, each at its maximum operating current, are shown in Figs. 1, 2 and 3. In this, and in all subsequent cases throughout this paper, these calculations are made according to the method previously described,[1] for the one best-focus condition giving maximum screen light. Each of these curves shows, on the left, the lumens through the motion picture aperture and, on the right, the light distribution across the aperture, each over a range of light-collecting angles from the source, and for a series of optical speeds into the aperture. Light losses due to absorption, shadowing and vignetting, which always occur in varying degree in any specific optical system, have not been included in these present calculations, a permissible simplification since only relative values are considered in the conclusions drawn here. A suitable loss correction of approximately 50% would

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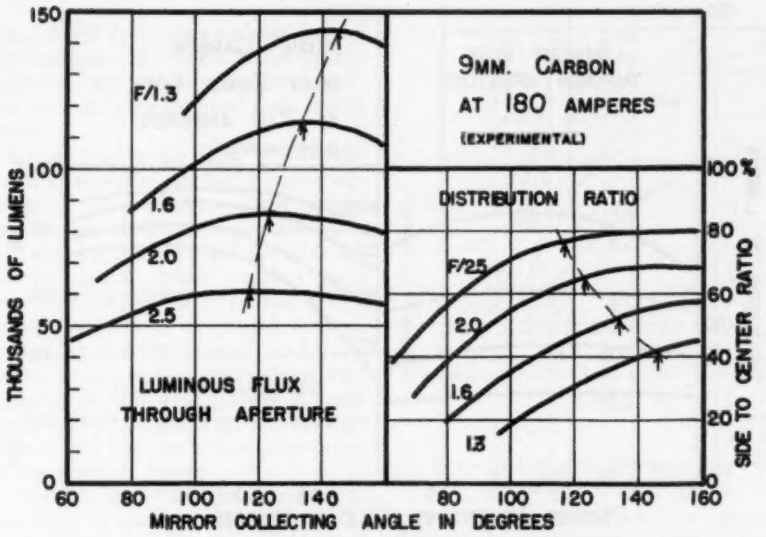

Fig. 1. Screen-light characteristics of an experimental 9-mm high-intensity positive carbon at its maximum operating current in water-cooled jaws.

NOTE: *All light and distribution values throughout this paper are based upon the best-focus condition giving maximum screen light.*

have to be applied to the lumen values given in this paper in order to determine the actual screen-light level in any particular instance. As an example, crater light measurements on an 8-mm to 7-mm "Suprex" trim at 70 amp, calculated for an *f*/2.0 mirror, predict a flux of 27,600 lm on the aperture, compared with 14,000 lm motion picture screen light realized in practice. This is because mirror absorption and reflectance losses, plus shadowing due to the positive head, etc., amount to about 20%; while of the total lumens passing the film aperture, no more than about 65% reaches the screen due to a combination of spill-over, vignetting and glass transmittance losses at the projection lens.

With respect to the aperture-lumen variations shown by Figs. 1, 2 and 3, these confirm the earlier conclusion[1] that maximum luminous flux is not necessarily obtained at the maximum collection angle; the simple concept that a bigger collection angle picks up more light from the source and hence delivers more light to the motion picture screen fails to work out. With a fixed speed into the aperture, the optical geometry is such that the magnification of the crater image on the aperture increases as the pickup angle increases, thus introducing a loss factor, working against the greater light collection. The light distribution characteristics of high-intensity carbon arcs are such that a collection angle is reached at each speed beyond which more light is thrown outside the aperture by the enlarged image than can be collected by the higher pickup angle. The exact pickup angle at which this maximum light value occurs will depend in each instance on the particular light distribution characteristics of the carbon in question. A small carbon, for instance, with a peaked light distribu-

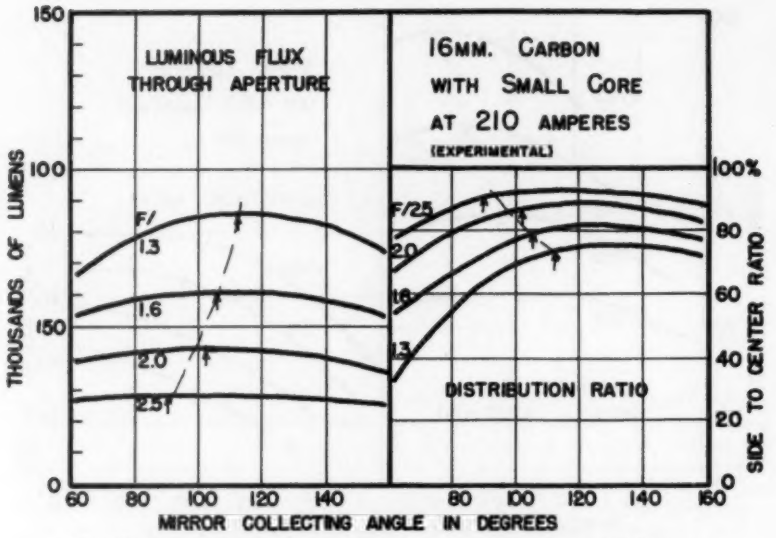

Fig. 2. Screen-light characteristics of an experimental 16-mm high-intensity positive carbon, with small core, at its maximum operating current in water-cooled jaws.

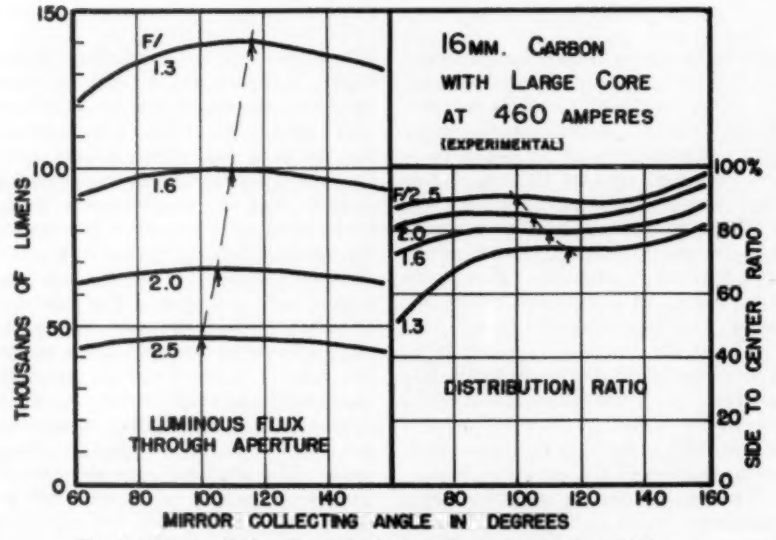

Fig. 3. Screen-light characteristics of an experimental 16-mm high-intensity positive carbon, with large core, at its maximum operating current in water-cooled jaws.

tion, effectively utilizes a higher magnification ratio and hence a higher pickup angle than is required with a larger carbon with a more uniform light distribution.

Figure 1 gives the light characteristics of an experimental 9-mm carbon operated at 180 amp, a very high current for this size. It is seen that high collection angles are effectively utilized at the various optical speeds to give good screen light values, but at comparatively low distribution ratios. Figure 2 shows the similar characteristics for an experimental 16-mm carbon with a small core, operated at 210 amp. Here a much smaller collection angle gives maximum screen light, and the distribution ratios are considerably higher.

Figure 3 shows the light-output characteristics of another experimental 16-mm carbon with a large core, operated at 460 amp, the maximum current used with any of the approximately 100 positive carbons upon which the conclusions of this paper are based. Particularly with this carbon, the light output and distribution ratio are comparatively insensitive to the choice of collecting angle, since, with the large core and high current, the effective source is quite large and of more uniform brightness.

It might be noted that in no case is a 100% distribution ratio reached. Particularly with the large-cored 16-mm carbon at $f/2.0$, the effective source size is quite sufficient to fill the aperture completely from all angles of view. However, the crater of any high-intensity carbon is always brightest near the center, and this peak is carried through as higher illumination in the center of the screen.

Data such as those shown in the preceding figures have been correlated for approximately 100 different positive carbons, both production and experimental types, of 9-, 11-, 13.6- and 16-mm diameter. It is, of course, recognized that the smaller 7- and 8-mm

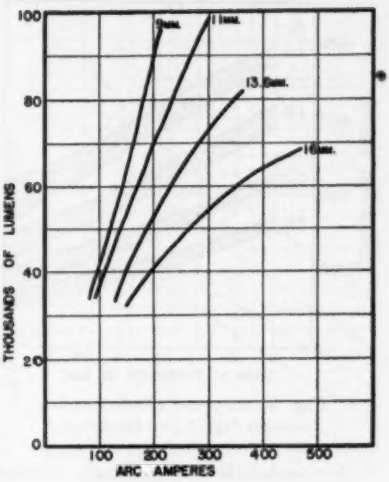

Fig. 4. Relation between screen light and arc current at an optical speed of $f/2.0$.

"Suprex" carbons are very important items, commercially, although they were not within the scope of the investigation reported here. Certain basic behaviors have been disclosed by these correlations. The first such relationship is that between screen lumens and arc current for various carbon sizes and optical speeds. Figure 4 shows this relationship at a speed of $f/2.0$ and for carbons of 9-, 11-, 13.6- and 16-mm diameter. Each curve results from measurements on a number of different-type carbons of a given size, each carbon represented by a single value determined at the maximum stable current for that carbon. For example, referring to the extreme points on the curve for the 16-mm size, one type of 16-mm positive carbon was found to give 32,000 lm at its maximum current of 150 amp; while another 16-mm positive carbon of very different construction gives 68,000 lm at its maximum current of 460 amp. The curves of Fig. 4 show the smallest carbon most efficient in current utilization, although, as will be indicated later,

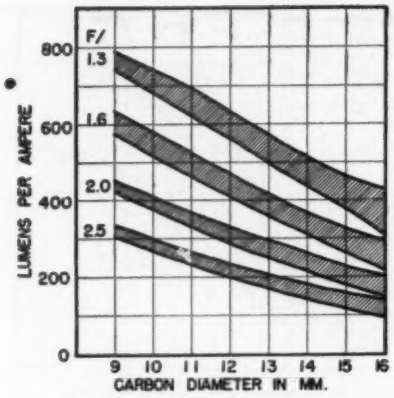

Fig. 5. Current efficiency in screen-light production.

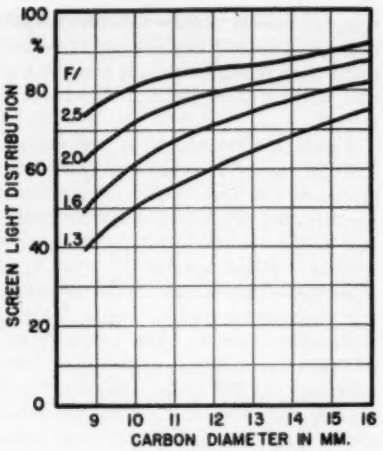

Fig. 6. Screen-light uniformity; side-to-center brightness ratio.

factors other than maximum current efficiency are involved in the choice of a preferred trim for a particular situation. It will be noted that the curves for the 13.6- and 16-mm carbon sizes are concave downward, indicating a falling-off in current efficiency with increasing amperage on a given size, which is probably the result of the inability to cool the larger diameters as effectively as the smaller. For instance, the 16-mm carbon at 150 amp gives more than 200 lm/amp; while the larger-cored 16-mm carbon at 460 amp gives only 150 lm/amp. This relationship is shown more directly by Fig. 5 which utilizes the data shown on Fig. 4, together with similar data calculated for the other optical speeds indicated. Here lumens-per-ampere are plotted against carbon diameter for each of four different optical speeds. Each curve is represented as a band, including the extremes in current efficiency encountered with each carbon size. Here again, the higher current efficiency of the small-diameter carbon is confirmed for each of the optical speeds investigated.

The data so far have been concerned only with current efficiency, and if this were the only criterion, the smallest possible carbon would always be chosen for a given job. However, no consideration has yet been given to the screen-light distribution ratio, the burning rate of the carbon or the color uniformity of the screen, all important factors in making a choice in any particular situation.

Figure 6 shows the variation in screen-light distribution ratio with carbon size, at the same optical speeds previously considered. Here the decided improvement in screen-light uniformity with increasing size is effectively demonstrated, particularly as the optical speed increases to give a steeper slope to the curve. The data shown in Fig. 6 represent the average for all the carbons tested, individual values showing some scattering around these curves, but not sufficient to invalidate the general trend. It should be pointed out, however, that, contrary to the general indication of Fig. 6. all 9-mm carbons, for instance, do not yield a lower screen-light distribution than all of 10-mm size. In fact, the reverse is sometimes the case in practical service comparisons. Different ratios of core to shell diameter, different methods of construction and burning, all contribute to the scattering previously described.

Two additional factors contribute to the screen distribution value actually achieved in a given commercial situation. The first is due to the slight departure in shape of all commercial lamp mirrors from the perfect ellipse assumed in the present calculations. Instead of all the crater images from all angles of view being precisely centered in the aperture, they are displaced in practice, by normal errors in mirror shape, to spread the light in less peaked fashion, but with negligible loss in total lumens on account of this spreading. In the second place, the projectionist, in adjusting his optics to give the best-looking screen, may decide upon a slightly out-of-focus setting, and sacrifice somewhat on screen light in favor of a flatter screen. The distribution values of Fig. 6, therefore, are not necessarily the same as those which would be obtained in a practical projector assembly, although the basic trends between sizes and optical speeds are as indicated.

Let us consider next the consumption rate of the carbon. This depends so much on carbon design, on the method of burning, whether the carbon is plated or unplated, whether it is burned with or without current jaws, and with or without water-cooling, that no simple relationship exists. However, in situations where equivalent screen light is given by carbons of different sizes the smaller carbon will always burn the faster. The exact magnitude and economic significance of this difference requires determination in each specific case, and is always an important factor to be considered. Blowing of the arc according to principles recently defined by Dr. Edgar Gretener,[2] is also a major factor in the determination of current and carbon efficiency. Apparently the light secured at a given current is very substantially increased by this blowing, while the carbon consumption per unit of light output is less markedly affected.

With respect to screen color, it is most difficult to express color differences

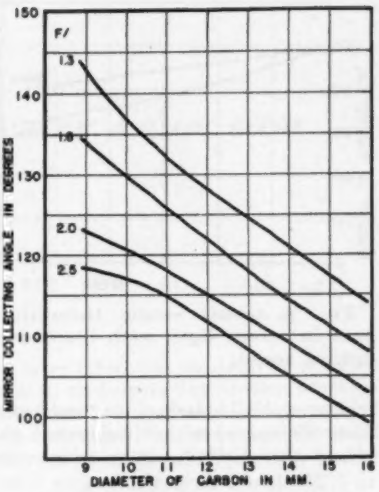

Fig. 7. Collecting angle giving maximum screen light.

in terms of numbers of true comparative significance, and no attempt has been made to do this with the various trends reported here. However, the larger carbon gives a more complete filling of the aperture from all angles of view, and also tends to give a more uniform screen color in any comparison of different sizes at equivalent light levels. Further, with the larger-sized carbon, screen light and color uniformity is better maintained over a wider range of maladjustment of the positive-carbon position.

It was previously indicated that the smaller carbon requires a higher collection angle for maximum screen light than does the larger carbon. This general relationship is indicated for four different optical speeds by the curves of Fig. 7. The increasing slope at the higher speed shows that this effect of carbon size becomes more pronounced as the speed increases.

Finally, the relationships plotted in Fig. 8 show that increases in optical speed into the aperture do not result in as great increases in illumination as the

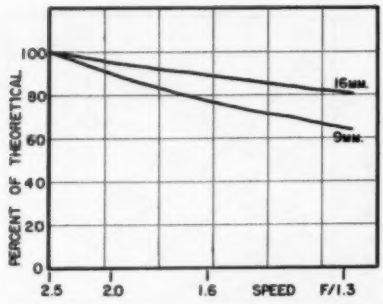

Fig. 8. Actual versus theoretical gain in screen light with increasing optical speed.

relative optical speeds alone would predict. Compared to the illumination obtained with an $f/2.5$ system, an increase to $f/2.0$ should theoretically give 6.25/4.00 or 1.56 times as much illumination. The ratio calculated with 16-mm carbons is 1.48, and for 9-mm carbons, 1.40—95% and 90%, respectively, of the theoretical amount. As might be expected, this departure from the theoretical is greatest for the smallest carbon, the reason being that the crater images on the aperture are not sufficiently large to fill the aperture completely at all angles of view, and that the brightness distribution across the crater is most peaked for the smaller carbons.

This paper thus defines certain basic relationships which should be recognized in the most effective development of the combined arc carbon and optical system to do a given job. Broadly speaking, a small carbon can be utilized to give highest current efficiency; this requires the use of a high collection angle, gives a less uniform screen-light distribution and screen color, and is more sensitive to light and color variations as the carbon is moved from the exact focal position. The larger carbons operate with lower current efficiency but give a higher quality performance in all other respects, at a higher cost. The choice in a particular situation should be based upon a balance of these various factors as applied to the specific economic considerations involved. As in other fields, there are proper applications for many possible combinations of cost and quality.

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The RCA PT–100 Theater Television Equipment

By Ralph V. Little, Jr.

The design of the first commercial theater television equipment is based on the experience gained from installing and operating earlier developmental equipments in theaters. Designed to augment the standard theater sound equipment, the PT-100 Television Equipment is intended to combine maximum reliability with performance limited only by the quality of the incoming signal.

SINCE THE EARLY STAGES of its development, engineers have visualized television as a natural entertainment medium for the theater, comparable to that of motion pictures. Years of engineering research and development, with special attention directed to the production of theater-size pictures have been rewarded. Theater projection television is no longer an engineer's dream but a current reality.

The first theater television equipment was demonstrated in 1929 at the RKO Proctor Theater in New York; the equipment used a mechanical scanning disc to produce a 48-line picture which was formed by video modulation of the light beam from an arc lamp source. During the interval of 20 years the all-electronic television system was devised with the substitution of the kinescope for the scanning disc followed by the addition of the iconoscope for use in the camera.

Paralleling the development of the basic technology of electronics, Dr. Epstein and Mr. Maloff were concentrating their efforts on the design of high-intensity kinescopes and of more effective optical systems which led to rapid advances in projection television during the years 1937–1940. By 1940, a modern prototype projection unit emerged from the laboratories to be demonstrated at the New Yorker Theater in 1941. The goal was now in view, but World War II delayed further development.

The interest of the film industry was enlisted in 1945 and 20th Century-Fox and Warner Bros. cooperated to have two of the 42-in. optical giants built by RCA. These equipments have been described and were demonstrated on several occasions during 1947 and one is still in use as a standard of excellence at the 20th Century-Fox Television Laboratory.

With this background of accumulated experience in the fields of television and

Presented on October 20, 1950, at the Society's Convention at Lake Placid, N.Y., by Ralph V. Little, Jr., Radio Corporation of America, RCA Victor Div., Camden, N.J.

tube techniques, we were ready to establish a product design of a theater television system.

Surveys were made of a number of representative theaters to determine the physical parameters into which a projection system might be integrated. There were many factors to be considered such as the requirements of performance, the limitation of present theater structures and the economics of the purchase and use.

Using initial prototype designs as a basis, a specification was submitted by 20th Century-Fox as a suggestion of the type of equipment which might be suited to the ultimate commercial use in the theater. Earl Sponable and H. J. Schlafly have been actively cooperating for four years in the development phases of the project and their efforts have served in a large measure to bring our new design to the industry. Warner Bros., through Col. Levenson, contributed their suggestions.

The goal of both the engineer and the theater industry is to develop theater television projection to equal or excel the industry standards for 35-mm motion picture film projection; under controlled conditions of pickup and transmission, the goal appears as a possibility. Evolution of an 8-mc video channel, used under ideal conditions of equipment adjustment, including correction for proper tone scale rendition, and having a high signal-to-noise ratio, should reproduce all the information in a frame of 35-mm motion picture film. The factors which require attention to produce the ultimate in picture acceptability are: (1) picture detail; (2) freedom from granular or other structure; (3) signal-to-noise ratio; and (4) tone-scale rendition.

Picture detail and structure must be discussed together as they have to do with the transmission bandwidth available. The present television broadcast channels limit the practical bandwith, via air transmission, to approximately 4.25 mc. The number of scanning lines is now 525, permitting a resolution of 340 lines horizontally and 400 lines vertically as seen by use of the Monoscope test pattern. At a 4:1 viewing distance, which is the minimum for home viewing, the scanning lines cannot be resolved by the eye so that the standards are considered adequate.

In order to accommodate the theater patrons, who will be closer to the screen than the minimum 4:1 distance, more picture detail and a greater number of scanning lines will be desirable. The selection of the number of scanning lines is a function of the economical bandwidth and a compromise on the balance between the resolution of the picture elements in the horizontal and vertical dimensions. With the 8-mc video band, selected for an example, we can determine the resolution capabilities of such a system.

It is to be noted that the present 4.25-mc broadcast standard permits a balanced horizontal and vertical resolution of approximately 400 television lines. An increase in the number of scanning lines, while retaining the bandwidth, reduces the horizontal detail as shown in Table I. The data indicate that an 8-mc system will give a balanced resolution when using 625

Table I. Television Resolution.*

		525	625	735	819
Vertical		488	582	683	762
Horizontal, Bandwidth	4.25 mc	340	283	240	216
	8 mc	640	533	453	407

*Scanning lines/60 fields, interlaced.

lines. The RCA PT–100 equipment has been designed to utilize the capabilities of a full 8-mc video channel.

The signal-to-noise ratio is an extremely important factor, probably the most important, if emphasis is to be placed on any one item. Motion picture film noise level, which until recently has not been quantitatively measured, should be the basis for an acceptable noise figure; the value of 42 db for the electrical maximum signal-to-noise has been suggested. The type of noise is important, as impulse type can be extremely troublesome because of its effect on the keyed d-c setting circuits. Also single-frequency noise will beat with the scanning frequency to form interference patterns which can be noticeable even though low in level

The fourth factor, tonal rendition, is also important and is dependent on the operating conditions of the camera in particular, and on the operation of the projector as a secondary effect.

When the camera characteristics can be well enough standardized, correction circuits can be introduced to enable the projector to produce pictures of photographic reproduction qualities. The SMPTE Committees on theater television are studying these problems and will be able to make recommendations to the industry for the necessary standards.

Details of the PT–100 Equipments

The design of the PT–100 projector is predicated on the choice of two elements of the projector: the kinescope and the optical system. The projection kinescope chosen for the design was a 7-in. tube to be operated at 80,000 v; it was desirable to choose the smallest tube consistent with high performance in light output, in resolution, and in detail contrast.

With the kinescope size chosen, the RCA Tube Division undertook the task of developing the 7NP4 to fill the needs of this design, which is described in detail in an accompanying paper in this issue of the JOURNAL.

Considerations of optical design require a careful analysis because they are the most costly elements of the equipment. Their selection had to be predicted on available manufacturing techniques for volume production of the glass blanks, the final grinding and the aluminizing. The cost of the optics and their mounting increases approximately as the square of the diameter. The production of the 42 in. mirror by laboratory methods was one thing on which cost was secondary, but the practical considerations indicated that a 26-in. mirror would present a good compromise.

With the kinescope size chosen and the mirror size roughly determined, it was a problem of optics to arrive at the proper design center which includes the faceplate of the kinescope as an element of the optical system.

The effective focal length finally chosen was 15.515 in., and Fig. 1 shows a chart of the operating conditions; the nominal projection throw is 62 ft from the face of the kinescope to the screen for a 20-ft wide picture. Since the "Schmidt" type system, as in the case of most other optics, is a fixed magnification device, the only variable is the picture size on the faceplate. Arbitrary limits are shown in the figure to indicate a degree of flexibility. The diagonals represent the diagonal raster sizes on the kinescope, the nominal size being 6¼ in. and shown as the center line.

The percentage figures show the relative screen brightness for various conditions of operation with 100% for the nominal light output at the design center.

With the limitation of the optics determined and the balcony location of the projector established, it was decided that a very minimum of equipment should be located in the theater auditorium.

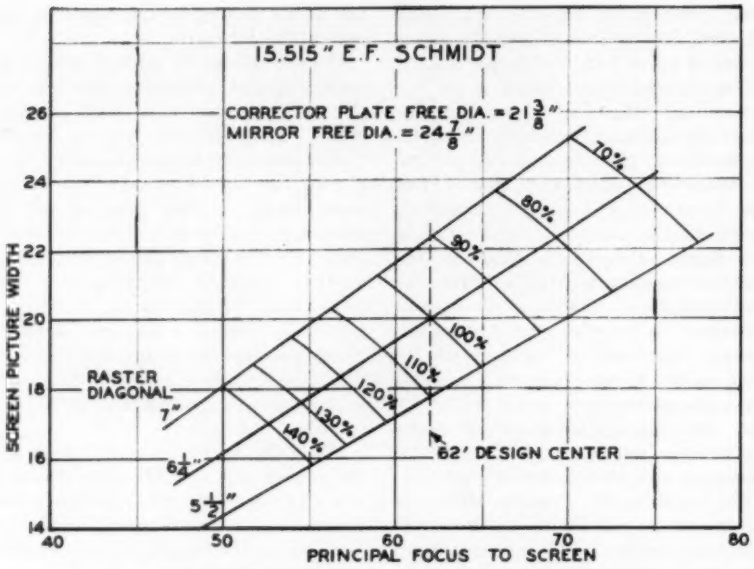

Fig. 1. Chart of 15.515-in. effective focal length lens operation.

Figure 2 gives a typical theater cross section showing how the projector would fit into a balcony-type house. The screen, due to the shallow depth of focus of the projector, is mounted normal to the projection axis. The arrangement in a non-balcony or stadium house would require that the nominal throw be kept and that the projector be mounted on a retractable boom from the ceiling.

The characteristics of the modulation, or video amplifier, made it necessary to place this element adjacent to the kinescope. In past designs it had also been necessary to include the horizontal scanning wave amplifier near the kinescope deflection yoke, but this required more cabling to the projector and a great deal of physical space; therefore, a premise of the present design was to place all of the deflection equipment in the booth racks. The only electronic element of the equipment now remaining in the projector housing is the video power amplifier. The projector consists then of the projection kinescope (the 7NP4) the optical elements, a 26-in. mirror with a 22-in. correction lens together with the mounting or support of these elements. The electrical equipment is kept to a minimum with the required video amplifier, a blower for cooling the kinescope faceplate, and the necessary terminal boards to facilitate interconnecting wiring.

The equipment location can be seen in Fig. 3 which is a photograph of the projector with one-half the outer housing removed. The wiring is accessible by lifting the top protective cover which reveals the terminal board wiring side of the video amplifier. The amplifier is hinged to be tilted up and to the side, making the tube side of the chassis accessible and permitting adjustment or replacement of the kinescope. The projector is interlocked through the control panel to remove the high voltage if the cover is raised; the interlock also actuates a shorting arm which contacts the

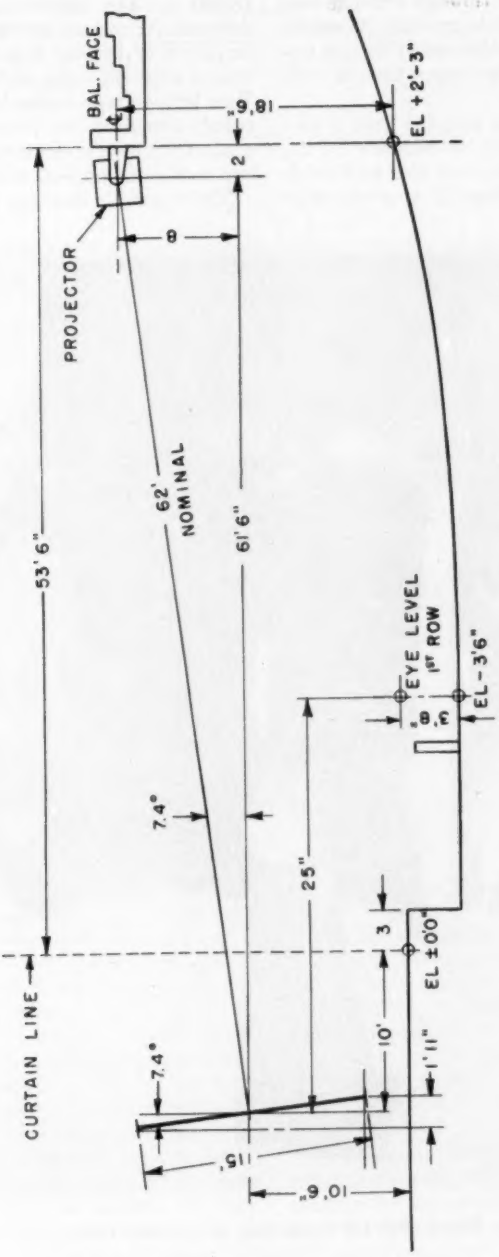

Fig. 2. Typical theater, cross section.

high-voltage feed through bushing connecting the circuit to ground. A lock on the cover gives added safety so that unauthorized persons cannot tamper with the equipment.

High voltage is supplied from a unit designed to furnish the 80,000 v for the accelerating anode and also to furnish the focusing voltage of approximately 18,000 v. The high-voltage supply is designed for remote operation and can be placed in a power or generator room near or adjacent to the projection booth. Two high-voltage cables lead from the supply directly to the projector and the control circuits are connected to the control rack in the projection booth.

The schematic diagram, Fig. 4, shows

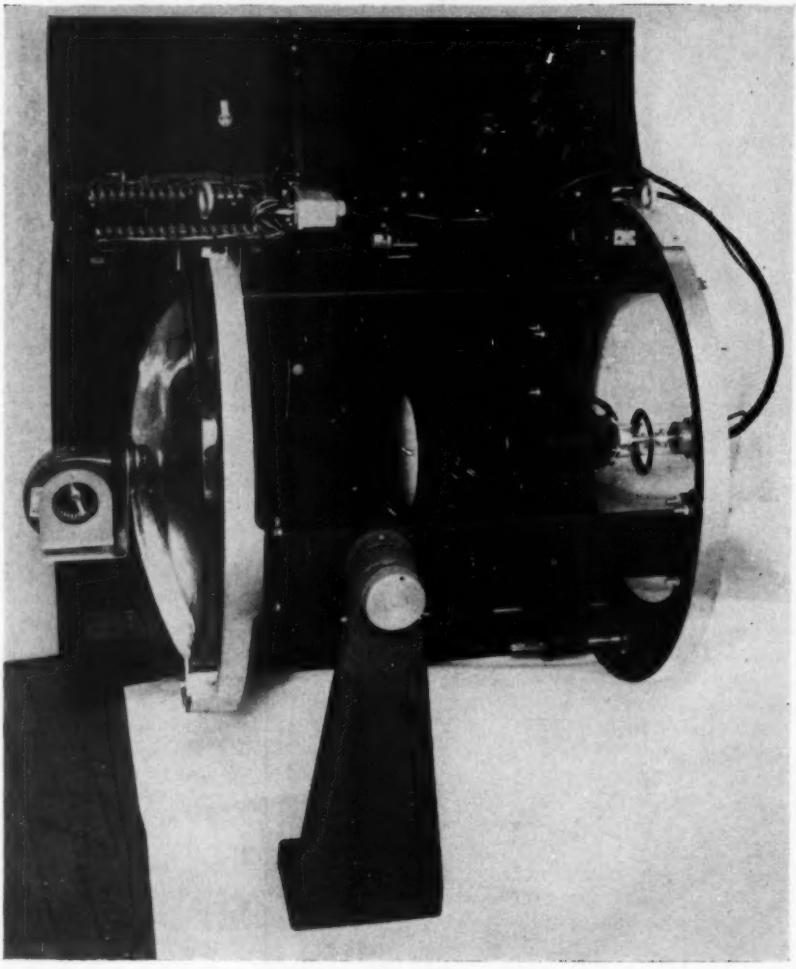

Fig. 3. PT-100 Projector, cover removed.

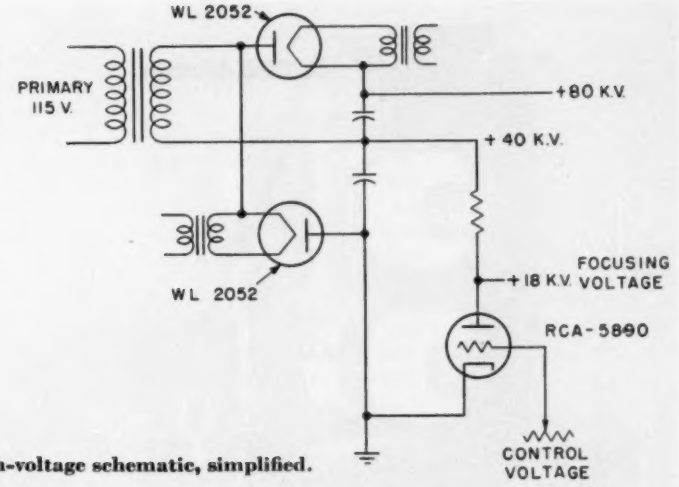

Fig. 4. High-voltage schematic, simplified.

the elements of the supply consisting of a 40,000-v transformer in a voltage-doubling rectifier circuit; the rectifier tubes are type WL2520 tubes. A special feature of this supply is the shunt regulator tube developed for remote adjustment of the focus voltage about its mean value of 18,000 v.

The tube for focusing is the RCA 5890; its use eliminates variable resistors with their attendant difficulty of insulation and stability at these high voltages. In addition to the basic elements, the high-voltage supply contains protective circuits to short the output voltages when power is removed. Metering circuits are also provided with remote indication on the control panel to show the proper functioning of the equipment; the metering shows the voltage and current being developed by the supply. In operation the meter gives knowledge of the proper functioning of the power supply; the current reading indicates that the kinescope is active and drawing power from the supply. The voltage indication shows the operation of the step-starting timer and shows when full voltage has been applied to the projector.

Figure 5, a photograph of the high-voltage supply, shows the unit with the rectifier tubes exposed for servicing. By loosening four nuts this panel may be raised to the position shown. Through very conservative design it is expected that the rectifier tubes will last from three to five years; in fact, the entire unit will give years of uninterrupted service with a minimum of servicing. The only service function consists of rotating the rectifier tubes at stated intervals to keep the spare tube properly activated.

Mechanical and Electrical Considerations

The block diagram, Fig. 6, shows the location of the various parts of the system. There are the three logical divisions of the equipment with their respective locations: the projector located in the theater, the projector control in the projection booth, and the high-voltage supply in the power or generator room.

The location of the operating equipment in the projection booth gives precedence for equipment design to conform to time-tested procedure of front

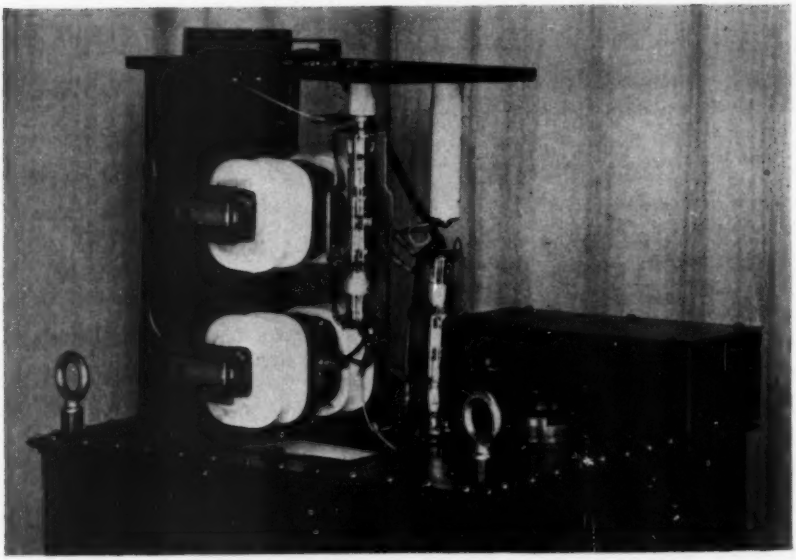

Fig. 5. High-voltage supply, tube-shelf open.

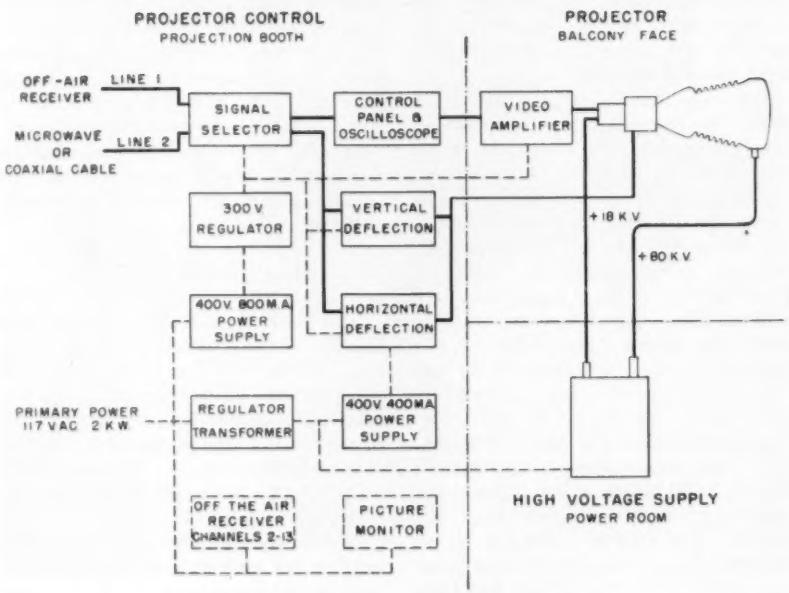

Fig. 6. PT-100; block diagram.

servicing of the equipment for theater work. The major electrical considerations, of course, are the Underwriter's requirements, and in addition, the utmost in component reliability due to the economic necessity of installing single-channel equipment with no stand-by or emergency service available.

The booth equipment consists of two short racks, one the projector control, the other the monitor rack. There are ten major units of equipment as shown by their respective blocks, and in addition, the necessary terminal boards and a high-voltage control panel.

The signal would enter the signal selector, which contains the video amplifier and synchronizing circuits, to be distributed to the control panel, the vertical deflection, and horizontal deflection units. An 800-ma, 400-v power supply makes regulated 300 v available through the regulator unit. The 400-ma, 400-v power supply furnishes power for the horizontal deflection and is fed from a 1-kw, regulating-type transformer which also provides a standard of reference for the high voltage. An off-the-air receiver and picture monitor complete the complement of the racks.

A typical chassis unit is shown in Fig. 7, as it is mounted in the rack and ready for operation. A removable cover can be taken off to check the tubes or the fuses. All individual chassis have the primary power fused, as are the plate voltages which have neon indicators on their circuits. The unit shown is the vertical deflection amplifier; Fig. 8 shows the interior exposed for servicing or adjustment of the infrequently used internal controls: the vertical hold, vertical size, vertical linearity and, on the rear panel, the vertical centering.

Miniature tubes are used whenever possible and, in order to avoid mounting of parts on those small tube sockets and to make the unit more accessible for manufacture and servicing, resistor boards are used to produce this trim design. The mechanical design was so proportioned to permit standardization of the chassis blanks and the covers; in addition, it presents a uniform overall appearance.

Circuit Operation

Electrically, the protection of the 7NP4 kinescope required a major part of the design effort. The expense of the

Fig. 7. Vertical deflection chassis, without cover.

kinescope and the necessity of ensuring that the tube fulfill its life expectancy made electronic protection a must item. Scanning failure could cause the faceplate of the tube to be burned so as to make it unusable and in the extreme case, with high-voltage beam concentrated on a single spot, that is without either vertical or horizontal scanning, it could melt a hole in the faceplate of the tube.

Protection to the kinescope has been provided for the following contingencies:

1. Open or shorted deflecting yoke,
2. Lack of drive due to tubes,
3. Loss of supply voltages,
4. Overdrive of kinescope (positive grid).

In operation, primary power is first applied for all electron-tube heaters and to the bias supply. A relay on the bias supply then closes, connecting primary power to the plate power supplies. Scanning will now be generated, but a series of interlocks must now be closed before the high voltage can be applied.

The following protection circuits must be functioned properly: the horizontal scanning; the vertical scanning; the electromechanical interlock on the projector cover must be closed; the vault high-voltage access door must be closed; then the high-voltage control circuit may be actuated. During operation excess video drive could damage the kinescope if it were not protected by an instantaneous bias control.

The most important consideration in the design of the protection system is the speed with which failure can be detected and corrective measures taken and, in addition, the circuits must fail safely. The circuits operate in such a manner as to drive the kinescope to beam cut-off (and this must be accomplished in a matter of less than 50 μ sec) and then the relays operate to remove the high-voltage power.

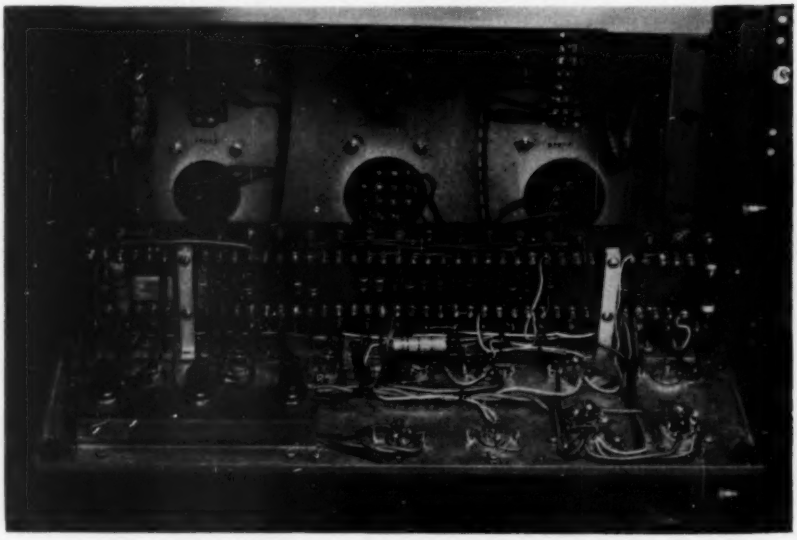

Fig. 8. Vertical deflection chassis, inside.

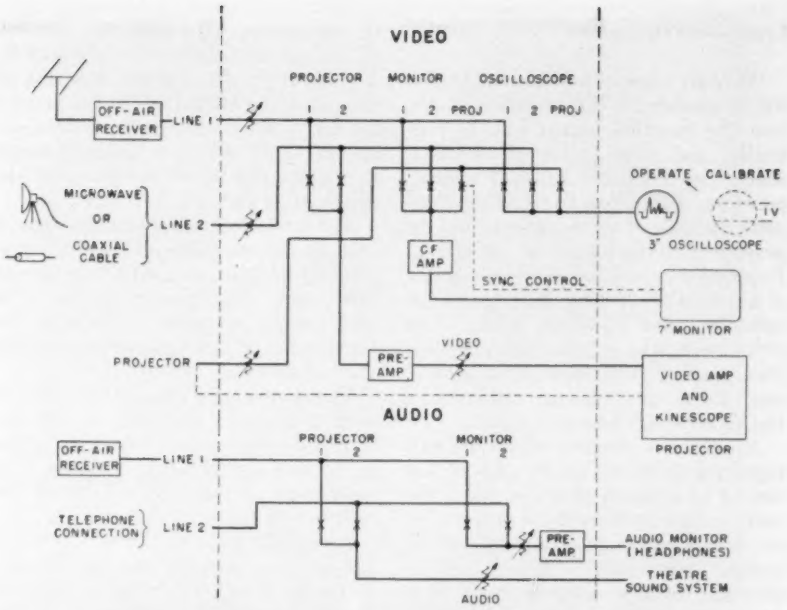

Fig. 9. Signal selector; simplified switching schematic.

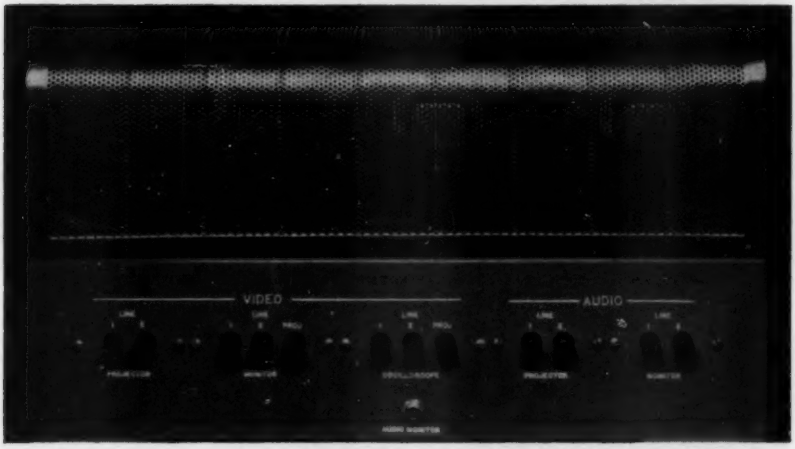

Fig. 10. Signal selector unit.

Equipment Operation

We must consider how the equipment will be operated in the projection booth, how the incoming signal will be controlled, and what points of operation should be checked. A signal selector panel was designed to facilitate the complete checking of the equipment prior to projection of the picture to the screen. Experience gained had shown the value of a system of checks to be made by the operator prior to show time. The switching will take care of two incoming lines each of video and audio signals, and also monitor the projector before the high-voltage power is applied.

An off-the-air receiver is provided as a signal source during the initial period of use, or as a source of test signal if the normal signal is to come via microwaves or coaxial cable. The receiver is normally connected to Line 1 and an alternate signal is connected to Line 2. As auxiliaries to the signal selector a 7-in. picture monitor and a 3-in. oscilloscope are used to check the projector functions without projecting a picture on the screen. The switching system of the signal is shown schematically in Fig. 9. It provides for the switching of the video and audio lines to the projector and to the theater sound system, respectively, as well as to an oscilloscope and a monitor which are provided for level setting and quality control.

The projector video amplifier has a cathode-follower video return which supplies a signal, attenuated by a ratio of 100:1 from the kinescope drive. The return signal is marked *Projector* on the signal selector, and the incoming signals marked *Line 1* and *Line 2*.

The oscilloscope is a 3RP1 provided with a 60-cycle sine-wave sweep, d-c setting for the vertical deflection, and a calibration circuit set to provide 1 v, peak-to-peak, marker lines when its switch is set on calibrate position.

In operation, Lines 1 and 2 are adjusted for level using the oscilloscope, and then, when normal level is provided to the kinescope, by operation of the video attenuator the level for the projector can be set by adjustment of the return line from the projector.

Fig. 11. Control panel.

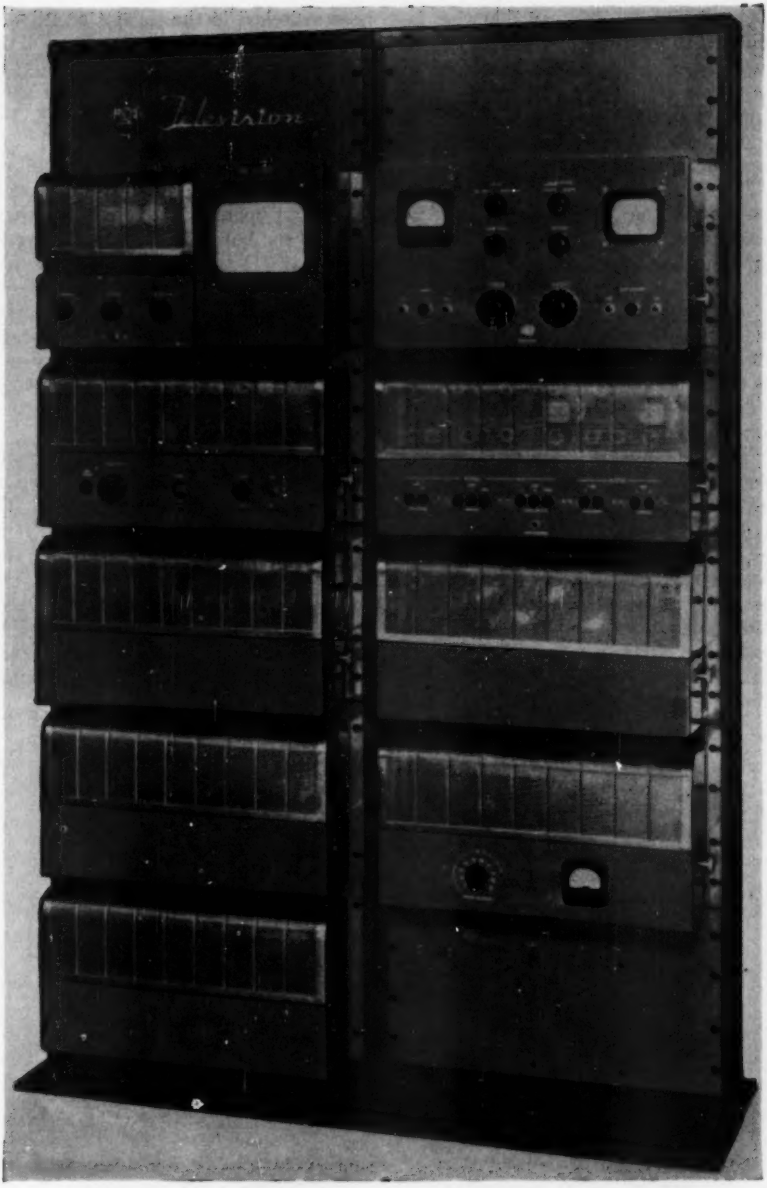

Fig. 12. PT-100 control and monitor racks.

The 7-in. monitor can likewise be switched to view the pictures on the incoming lines or from the kinescope in the projector; when on the projector, a complete system-operation check is obtained without requiring the picture on the theater screen.

The monitor is provided with driving pulses from the projector scanning circuits; it then shows the operation of the scanning lock-in as well as the picture quality; otherwise the monitor is synchronized from the incoming signal. The power supply for the monitor is self-contained making it independent of the operation of the projector.

The audio signal can be obtained from either Line 1, which is the off-the-air receiver, or Line 2 which may be a telephone line connection. Projector audio would normally be connected to the theater motion picture sound system and is provided with an attenuator for level setting. In order to be able to check the presence of incoming signal before operations, a preamplifier and headphone circuit are provided with its own switching circuit, audio monitor Line 1—Line 2. When the audio has been switched to the theater sound circuit, the normal monitor speaker will be in operation. Figure 10 shows the signal selector unit and the pushbutton controls are clearly identified with their respective functions.

The control panel is the focal point of the operation and to fill the requirement of ease of operation, the controls were kept to the bare essentials. The panel contains: (1) the a-c control elements, the power and high-voltage on-off switch buttons; (2) a 3-in. oscilloscope for level setting; (3) a meter to indicate operation of the high-voltage supply and kinescope; (4) the operating controls for the video and audio; and (5) interlock indicator.

For the operation of the equipment the functions of the control are shown in Fig. 11, with each control marked. To place the equipment in operation, it is only necessary to apply power by the power-on button; then to connect the equipment to the incoming signal and perform checks which are possible through the operation of the signal selector in conjunction with the monitor and oscilloscope.

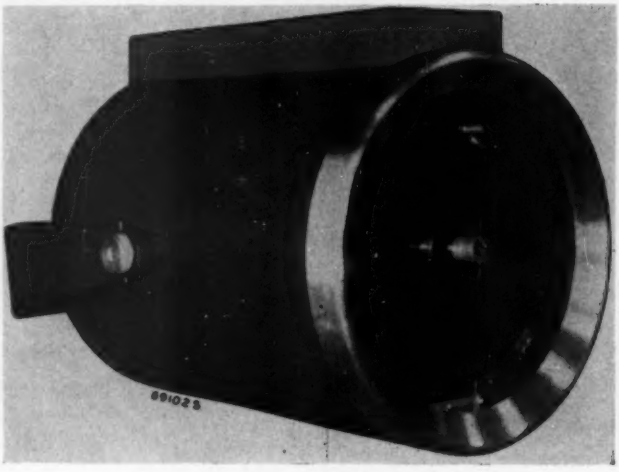

Fig. 13. Projector.

Figure 12 shows the projection booth equipment consisting of the projector control rack on the right and the monitor rack on the left. The units of equipment from top to bottom are: the projector control, the signal selector, the horizontal deflection amplifier, the 300-v regulator, and the high-voltage control panel. The picture monitor is the top unit in its rack; below the receiver for off-the-air reception, the vertical deflection amplifier, the 400-v, 400-ma power supply and the 400-v, 800-ma power supply. Several of the units of this equipment have not been described because of their conventional design.

The projector is shown in Fig. 13, an external view of the completed unit ready for installation on the theater balcony face.

Theater television as an entertainment medium has now reached the stage where a practical commercial equipment has been produced. To date, nine installations of the PT–100 equipment are in operation. The problems now lie with the industry in the field application: the best way to transmit the program to the theater, the type of programming best suited for this new medium, and, most important in the long view, how will picture quality best be maintained from the program subject through the long chain of electronic events before the picture image is viewed on the theater screen? Every effort, in the design of the PT–100 equipment, has been concentrated on building a quality product engineered for present-day use, and providing for standards which may be expected in the future as the needs of the industry are crystallized through the SMPTE.

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Projection Kinescope 7NP4 for Theater Television

By L. E. Swedlund and C. W. Thierfelder

The paper describes the design and development of the 7NP4, a 7-in., 80-kv kinescope which is capable of providing clear, bright, theater-size (15 × 20 ft) television pictures. The development involved solving design problems including: (1) a high-efficiency, low-color-shift, white fluorescent screen; (2) adequate high-voltage insulation; and (3) a gun to provide electrostatic focus of a high-current beam into a small, sharp spot, and magnetic deflection through a relatively narrow angle to conserve deflection power and provide essentially uniform focus over the entire picture area.

THE 7NP4 is a high-voltage, projection-type kinescope which provides a large, clear, theater-size picture when operated with a suitable reflective optical system. The primary goal in the design of this kinescope was to provide a very bright fluorescent image of adequate resolution and contrast. In order to obtain an optimum design, virtually every element of the kinescope was investigated and improved.

At the beginning of the development of projection-type television in 1930, the light output from fluorescent screens was far from adequate for large projected pictures, even with low resolution standards. Consequently, methods other than direct projection from cathode-ray tubes having fluorescent screens were investigated. These alternative methods fall into two classes: one using a cathode-ray tube having an incandescent or "cando-luminescent" screen, the other using a light-valve type of tube.[1] The former proved to be less efficient in producing light output than a fluorescent screen and also much more subject to overload damage. More success was attained with the light-valve method. This system depends on building up a temporary transparency that is intensely illuminated by a source of continuous light and is projected on the viewing screen with a lens. In general, both designs suffer from low optical efficiency, low resolution and low contrast. The use of intermediate film, which also can be classed as a light-valve method, is perhaps the most successful of the group. Compared to

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direct projection from a kinescope having a fluorescent screen, the use of intermediate film has the disadvantages of time delay before projection, loss of resolution, the need for additional specialized operating personnel, and the high cost of film and processing. It has advantages, however, in that it can use standard movie projectors and provide a record for repeated showings.

Optical projection of cathode-ray tube luminescent images received attention from the advent of cathode-ray tube television, but initially the low tube-screen brightness, combined with low-efficiency optical systems, resulted in very dim images, even on small screens. The development of the Schmidt camera lens for cathode-ray tube projection,[2] giving an approximately fivefold gain in optical efficiency over the best refractive optical system, marked a considerable advance toward the realization of theater-size television pictures. In 1941, a system of this type, utilizing a 7½-in. kinescope operating at 65 kv, was demonstrated in New York City.[3] This development was interrupted by the war, but since its resumption, continuous progress has been made, not only in increasing light output, but also in improving quality, reliability and tube life.

Light-Output Factors

The light output of a luminescent screen in a kinescope depends primarily on the energy of the electron beam and the light-conversion efficiency of the screen. The electron energy per unit time is the product of beam voltage and current. The maximum value of beam current at a given beam voltage is determined by the rate at which the energy of the electron beam can be absorbed by the phosphor, and by the maximum current which can be sharply focused by the electron gun. As a result, the beam current is limited to a few milliamperes. The principal means of increasing the energy, therefore, is to raise the beam voltage. In addition to increasing the energy of the electron beam, a higher beam voltage improves the light-conversion efficiency of the luminescent screen and permits a higher-current electron beam to be sharply focused by the electron gun. Maximum light output, therefore, increases with voltage at a greater rate than indicated by a linear relationship between the two. Raising the voltage, however, makes necessary the provision of better insulation and higher deflection energy; hence a voltage limit is introduced which depends on how well these requirements can be met.

The efficiency of the conversion of electron beam energy into visible light is determined chiefly by the choice of materials used in the fluorescent screen. The density of the electron beam striking these materials is also a factor influencing the efficiency.

High light output from the 7NP4 is obtained chiefly by using a high-efficiency screen and an 80-kv anode potential.

Size of 7NP4 Screen

The light output of a projection kinescope can be increased somewhat if the size of the luminescent screen is increased. This method of raising the light output is of secondary importance, however, and is limited by the desirable and practical bulk and cost of the optical system.

The increase in light output with increasing screen size is made possible by the attainment of higher conversion efficiency. The factors responsible for the variation of efficiency with varying screen size are: (1) the current density saturation of the luminescent screen material and (2) the temperature of the screen. The larger focused spot on a larger screen results in lower current density and hence in less saturation. The greater cooling surface and lower

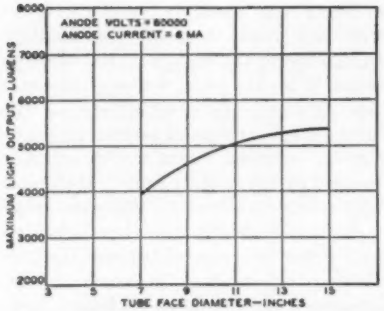

Fig. 1. Variation of maximum light output with changing screen size.

power density permit operation at a lower screen temperature. Figure 1 shows the variation in peak light output with screen size.

Although an increase in screen dimensions does permit some increase in light-conversion efficiency, it does not permit appreciable increase in beam energy. It might seem that the use of a larger screen, by permitting the employment of a larger spot for the same resolution, would permit the use of a higher beam current. But this is not so. Even when beam current is held constant, the spot size increases practically in proportion with screen size, for a given deflecting angle and beam voltage. Therefore, an increase in current would enlarge the spot size beyond the limit imposed by the requirement for good resolution.

In spite of the fact that a larger screen results in somewhat greater light output, the size, weight and cost of the optical system increase so rapidly with increasing screen diameter that practical considerations limit the size of the screen. The volume and weight of the optical system are approximately proportional to the cube of the kinescope diameter, and the cost of the optical system increases approximately as the square of the kinescope diameter. Projection kinescopes with diameters of up to 15 in. have been experimentally made and tested. It is found that a kinescope with a faceplate diameter of 7 in. gives a good balance between the light output and the bulk and cost of the reflective projector.

Screen Materials

A luminescent screen with a high efficiency in converting the electron beam energy into light was one of the goals in the development of the 7NP4. Sulfide-type phosphors are normally the most efficient, but, because of current-saturation effects, their efficiency is inferior at the high current density used in a projection tube. Silicate-type phosphors are less efficient at low current densities but, because they undergo less saturation, their over-all efficiency in a projection tube is greater. They are, therefore, preferred for this application. There are relatively efficient silicates which emit in the yellow-orange spectrum, but unfortunately the blue-emitting silicate has rather low efficiency, although it has even less current saturation than the yellow-emitting material. If the screen is composed of a mixture of yellow-emitting silicate and blue-emitting sulfide, the efficiency will be relatively high but the color will shift toward the yellow as the current density is increased. This color shift is objectionable but can be reduced by settling the sulfide against the glass faceplate and the silicate in a layer next to it, exposed to the incident electron beam. Then, since the beam is partly absorbed and diffused while it is penetrating the silicate layer, the current density is lower when the beam reaches the sulfide. But even with the reduction in current density due to the relatively thick layer of screen material required for efficient high-voltage operation, the color shift is still objectionable. The color shift was finally reduced to a negligible value by the substitution of blue-emitting silicate-type

phosphor for part of the blue-emitting sulfide phosphor.

The optimum screen weight for the 7NP4 is approximately 8 mg of phosphor material per square centimeter. This value is about three times as great as that used in a low-voltage kinescope of the directly-viewed type. An important feature is the aluminum surface applied to the back of the screen to maintain it at full operating potential and to reflect light from the back to the front.[4]

Insulation Considerations

In the projection tube the external high-potential and low-potential terminals cannot be separated by the full length of the tube, as is done in X-ray tubes. A deflecting yoke which is approximately at cathode potential is fitted over the projection tube neck, near the midsection of the tube. Therefore, the full anode potential is applied over half the tube length. The yoke is grounded and the cathode should be operated at or near ground, rather than negative to ground as in X-ray tubes, in order to facilitate the design and production of equipment using the 7NP4.

Adequate air insulation is obtained for the projection tube by placing the anode terminal as near the face of the tube as possible and by selecting a narrow deflection angle to make the cone long. The surface leakage path is increased by molding circumferential corrugations in the cone section of the bulb. In order to avoid the formation of a film of moisture on the glass, which tends to promote corona and arcing, the cone is coated with a moisture-repellent, insulating lacquer coating. This coating is colored black to help reduce stray light reflections in the optical barrel (Fig. 2).

The air space between the yoke and the neck may be another source of corona and breakdown because it is a dielectric in series with the glass neck, and the full anode voltage is applied across the two. Due to the fact that the air has a much lower dielectric constant than the glass, it is subjected to a higher voltage stress and may break down. Such breakdown would result in corona, heating and possible failure of the glass insulation. This voltage stress is avoided by applying a conducting lacquer to this part of the neck and connecting it to ground.

Fig. 2. Photograph of 7NP4 kinescope.

Internally the cone is at anode potential from the luminescent screen to the anode end of the electron gun (Fig. 3).

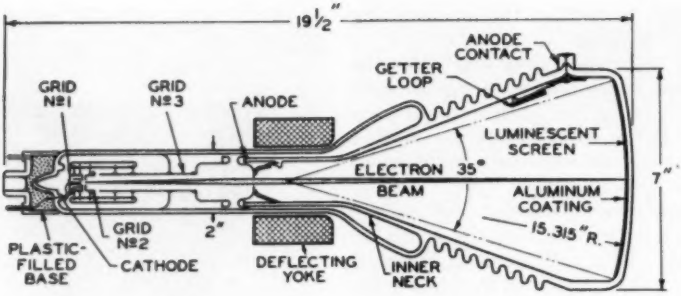

Fig. 3. Cross section of 7NP4 kinescope.

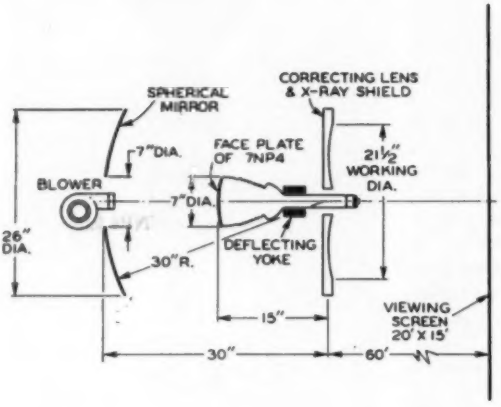

Fig. 4. Typical optical and cooling system for theater - television projector using 7NP4 kinescope.

Thus, the full anode voltage is applied between the outer conducting lacquer and the inside of the neck under the yoke. In a conventional design, therefore, the glass wall of the neck of the tube would be stressed by the full 80-kv potential difference. But it is difficult to make a glass wall uniform enough to withstand more than 40 kv. The insulation problem posed by this property of glass was solved by D. W. Epstein who placed a second, larger neck around the portion of the neck carrying the high anode voltage and provided vacuum insulation between the two necks.

Another insulation problem was to provide an external terminal for the focusing electrode, which operates at 17 kv. A first attempt at solving this problem was made by sealing a terminal in the glass neck. This terminal, however, had to be flush with the surface in order to provide clearance for the yoke. A better method of making contact was sought in order to obtain a trouble-free connection and to facilitate insertion and removal of the tube from the projector. After various materials and structures for the stem leads and base insulation were investigated, it was found that if a plastic material having high dielectric strength replaced the air in the space inside the base, the

focusing voltage connection could be made through the base. A novel procedure developed for producing this structure consists of filling the base with an exothermic plastic mixture and polymerizing it in place. The plastic also serves to cement the base to the neck.

Faceplate Considerations

The faceplate of the 7NP4 projection kinescope is designed to be used in a Schmidt-type reflective optical system (Fig. 4) and as such has to be a precision optical element accurately aligned with the rest of the system. The faceplate is a spherical section with a radius of curvature of 15.315 in. as required by the design of the optical system. It is not difficult to grind and polish the faceplate glass to the desired optical tolerance, but unless special techniques are used when it is being sealed to the cone of the bulb, it is distorted much more than can be tolerated. It was found desirable to grind the glass to a radius of curvature slightly greater than that required by the optical system and to allow the radius to decrease during the controlled sealing and glass-annealing operations. The glass face is accurately aligned with the bulb neck in order to minimize the amount of adjustment needed in the projector.

It has been known for many years that glass darkens when subjected to high-voltage electron and X-ray bombardment. This phenomenon is readily observed in X-ray tubes, but it is not objectionable there because it does not affect X-ray transmission. The color of the darkening is usually a yellowish brown and its intensity varies considerably with the glass composition. The soft glasses, such as ordinary window glass, darken much more quickly than the hard or borosilicate glasses and cannot be cleared or bleached appreciably by heating as can many of the latter types. The darkening appears to be due partly to electron bombardment of the glass, which affects the surface, and partly to X-ray bombardment, which produces a darkening that extends into the body of the glass. The darkening caused by X-rays can be bleached by heating the glass to about 200 C with infrared radiation.

Corning Type 774 Pyrex glass, a hard glass commonly used for laboratory and high-voltage glassware, darkens objectionably in about 50 hr of operation when used in an 80-kv theater-projection kinescope. Extensive tests over a long period of time were run in cooperation with the glass companies to find or develop a glass which would evidence little or no darkening. Although a few were found, they had other characteristics which made them unsuitable. Finally, methods were devised for overcoming the optical deficiencies of one of these types having little darkening, and this glass, Corning Type 707, was chosen for the 7NP4. This glass is a low thermal-expansion, hard glass, originally developed to have good high-voltage and electrical loss characteristics. Until recently, however, this glass had not been produced with satisfactory optical quality. But when special care is exercised and larger melts are made, 707 glass of relatively good optical quality is obtainable. A few seeds or small bubbles have to be tolerated but the faceplates are selected so that these blemishes are not near the inside surface. Because the optical system has a very shallow depth of focus, these imperfections are not noticeable in the image. This glass does darken gradually, but it can be bleached by heating with infrared radiation lamps for about 20 min as shown in Fig. 5. This treatment should not be needed before about 150 hr of operation.

Electron Gun Considerations

The electron gun must project a very intense electron image on the luminescent screen. The spot diameter at maximum current should not be much

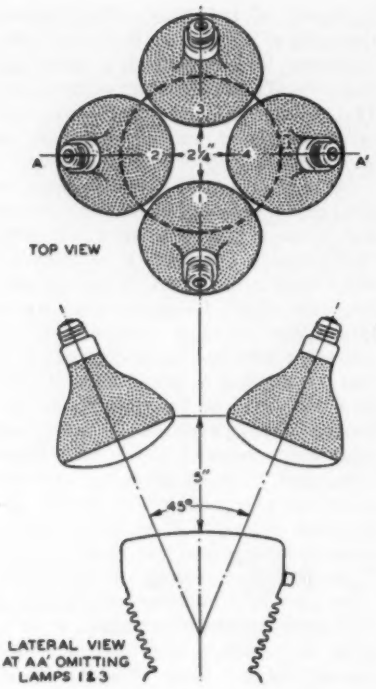

Fig. 5. Arrangement of infrared lamps for bleaching 7NP4 faceplate.

larger than the line width of a 525-line image on this tube (7.5 mils). The spot size will decrease with current, a tendency which helps to improve shadow detail. Because, on the other hand, deflection acts to increase spot size, some allowance has to be made for this effect. The electron beam can be focused either with an external magnetic field or an internal electrostatic field. With good design, both systems can be made to function with negligible aberration; the choice, therefore, can be made on the basis of ease of manufacture and ease of mounting and operating the tube.

In a reflective optical system, the kinescope and its accessories block out reflected light. For this type of application, therefore, electrostatic focusing is preferable because it results in more compact kinescope accessories and removes the problem of providing support and adjustments for a relatively heavy magnetic focusing coil. Electrostatic focusing voltage may be obtained from a bleeder resistance across part of the anode-voltage supply. This method is advantageous because it provides automatic correction of focus. As the brightness of the image varies, the load on the voltage-anode supply changes, causing the voltage applied to the focusing electrode to vary. A change in focusing-electrode voltage occasioned, for instance, by a switch from a dark to a bright picture, results in a change of focus such that a sharp picture is maintained. In contrast, with magnetic focus the focusing field is manually adjusted and is not readily controlled automatically because of the inductance of the focusing coil.

A further reason for using electrostatic focusing in the 7NP4 is that this type of focusing reduces an insulation problem. The voltage across the gap between the anode and the adjacent focusing electrode is about 63 kv. With magnetic focusing, the voltage across the gap between anode and the adjacent point of the electron gun would be 80 kv. An additional advantage is that, when the RCA 5890, a new high-voltage regulator tube, is used, one may adjust the focusing voltage with a low-voltage, low-current, remote-control potentiometer. A disadvantage of electrostatic focus compared with magnetic focus is that it increases the difficulty of tube manufacture, because the gun is a little more complex. Nearly perfectly circular electrodes must be provided to produce the symmetrical focusing field required for a round spot.

The electron gun in this tube has an oxide-coated cathode. The voltage rating of the gun is probably higher than that of any other vacuum-tube unit

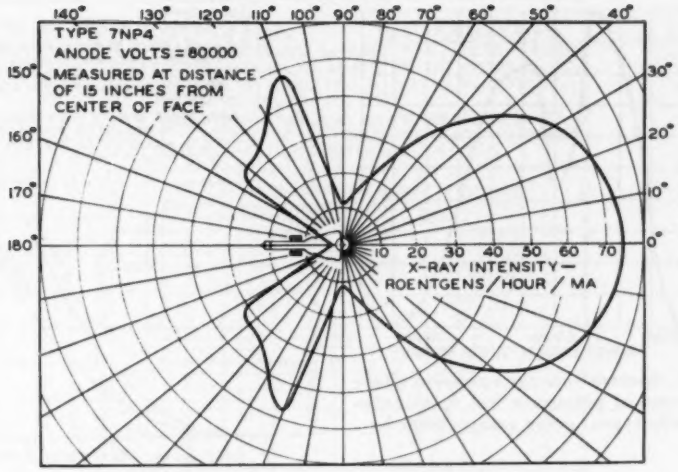

Fig. 6. Polar distribution of X-Ray radiation from 7NP4.

with an oxide-coated cathode. An oxide-coated cathode is desirable because its high emission permits formation of a high-current-density beam and thus helps provide sharp focus. Furthermore its low work function greatly reduces the control voltage required. Reliable operation of an oxide-coated cathode at very high voltage is made possible by means of excellent exhaust and getter systems which produce and maintain a very low gas pressure and limit ion bombardment of the cathode surface. The getter is flashed over the entire inside surface of the cone, providing a relatively large active area close to the main sources of ionized gas molecules. A getter flash over the inside of the bulb is possible because the aluminum screen backing protects the luminescent screen and because a deposit of getter on the screen does not appreciably reduce the energy of the high-voltage beam.

Deflection Considerations

Magnetic, rather than electrostatic, deflection is always used for high-voltage cathode-ray tubes to avoid insulation and distortion problems inherent with the latter.

A smaller deflection angle than that used in kinescopes for home-television receivers was chosen for the 7NP4 in order to reduce deflection-power requirements and to minimize loss of edge resolution. The larger-diameter neck required for the double-neck insulation makes deflection more difficult because the length of the deflecting yoke field is determined by the clearance of the inside neck. The deflecting power needed is of reasonable proportion, however, being not much greater than that required for wide deflection-angle, home-television receivers. A good margin of deflection power for reliability and good linearity is, therefore, readily provided. A narrow deflection angle also requires an increase in the distance between the electron gun and the screen. The increase in distance increases spot magnification, but this effect is compensated for by making the electron gun longer.

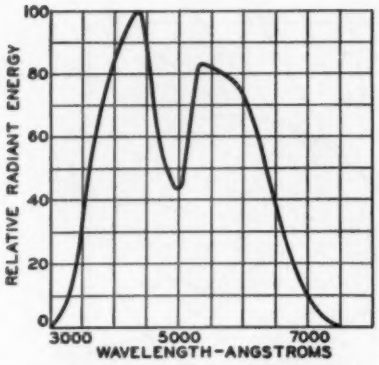

Fig. 7. Spectral-energy emission characteristic of phosphor No. 4, silicate-sulfide type; color temp., 6300 K.

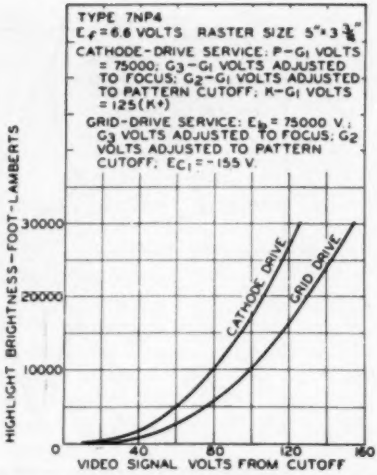
TYPE 7NP4
E_f = 6.6 VOLTS RASTER SIZE 5" × 3 1/8"
CATHODE-DRIVE SERVICE: P-G1 VOLTS = 75000; G3-G1 VOLTS ADJUSTED TO FOCUS; G2-G1 VOLTS ADJUSTED TO PATTERN CUTOFF; K-G1 VOLTS = 125(K+)
GRID-DRIVE SERVICE: E_{bb} = 75000 V.; G3 VOLTS ADJUSTED TO FOCUS; G2 VOLTS ADJUSTED TO PATTERN CUTOFF; E_{C_1} = -155 V.
HIGHLIGHT BRIGHTNESS-FOOT-LAMBERTS
30000
20000
10000
0
CATHODE DRIVE
GRID DRIVE
40
80
120
160
VIDEO SIGNAL VOLTS FROM CUTOFF

Fig. 8. Average drive characteristics of 7NP4.

Application and Operation

The 7NP4 operates at a voltage which produces penetrating X-rays. The radiation is emitted in a pattern that is symmetrical about the tube axis, as shown in Fig. 6. The X-ray intensity indicated is representative of normal operation. Although this level is low compared to that of a commercial X-ray tube, it is several thousand times the safe level for continuous exposure at close range. Sufficient shielding can readily be provided by enclosing the optical system in a metal barrel. Because radiation may extend for several feet in front of the projector, an X-ray-absorbing window may be needed.

The screen emits white light which has an equivalent black-body color temperature of approximately 6300 K. The spectral distribution of the energy emitted by the screen is shown in Fig. 7. At peak light output the maximum power input to the screen is approximately 480 w. For this condition the peak power in the beam is approximately 1000 kw/sq cm. This power density is extremely high and it is only because the spot moves across the screen at high velocity that the screen is not destroyed. Hence it is extremely important to provide full scanning at all times when the beam is on.

The faceplate of the 7NP4 is an optical component and has to be accurately positioned in the optical system. The high-voltage anode terminal is near the faceplate, so a support here to position the faceplate would require full anode-voltage insulation. The deflecting yoke is at ground potential and is thus a more convenient place to support this tube. Due to the method of assembly of the glass bulb parts, the neck is well aligned with the faceplate, but lateral as well as longitudinal adjustments are needed to position and focus the luminescent screen properly in the optical system.

In normal operation 80 to 160 w may be dissipated at the screen. With only radiation and convection cooling, this dissipated power would produce an excessive temperature and thus reduce the efficiency of the luminescent screen and possibly fracture the glass. A stream of air from a small blower, directed perpendicularly at the faceplate through a hole in the center of the mirror, is sufficient to keep the glass temperature

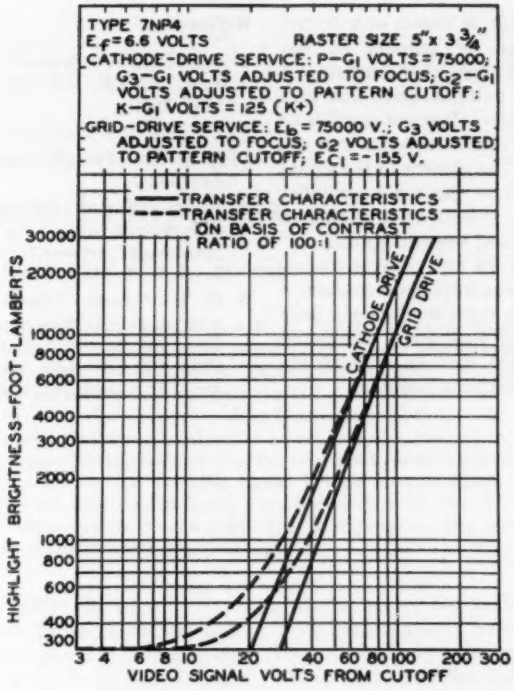
TYPE 7NP4
E_f = 6.6 VOLTS
RASTER SIZE 5" x 3 3/4"
CATHODE-DRIVE SERVICE: P-G_1 VOLTS = 75000; G_3-G_1 VOLTS ADJUSTED TO FOCUS; G_2-G_1 VOLTS ADJUSTED TO PATTERN CUTOFF; K-G_1 VOLTS = 125 (K+)
GRID-DRIVE SERVICE: E_b = 75000 V.; G_3 VOLTS ADJUSTED TO FOCUS; G_2 VOLTS ADJUSTED TO PATTERN CUTOFF; E_{C_1} = -155 V.
TRANSFER CHARACTERISTICS
TRANSFER CHARACTERISTICS ON BASIS OF CONTRAST RATIO OF 100:1
CATHODE DRIVE
GRID DRIVE
HIGHLIGHT BRIGHTNESS-FOOT-LAMBERTS
30000
20000
10000
8000
6000
4000
3000
2000
1000
800
600
400
300
3 4 6 8 10 20 40 60 80 100 200 300
VIDEO SIGNAL VOLTS FROM CUTOFF

Fig. 9. Average drive characteristics of 7NP4 in log-log coordinates.

below 100 C, the recommended maximum temperature for the outside of the face glass. The cooling air should be filtered to eliminate dust and minimize moisture formation inside the optical barrel.

Because of the relatively high beam current desired, an average grid-drive voltage of 155 v is needed. Inasmuch as a generous video bandwidth is needed to produce good detail, it is desirable to reduce this voltage requirement if possible. A worth-while gain is obtained by applying the video signal to the cathode instead of to grid No. 1. For example, with grid No. 1 grounded and the signal applied to drive the cathode negative, the grid No. 1-to-cathode voltage decreases and in addition, the grid No. 2-to-cathode voltage increases (Fig. 8). Both actions increase the beam current. The signal required is thereby reduced to 125 v by the compound action of the drive voltage.

Figure 9 shows the transfer characteristics on a log–log graph in the form used to indicate photographic film characteristics. This form of presentation has been described by O. H. Schade.[5] The transfer characteristic is obtained by measuring the brightness of an unmodulated raster. In an actual picture some light is scattered into the black areas. This effect will vary with the type of picture, but 1% of scattering is a representative value. The result is a contrast ratio of 100:1 in the luminescent screen. A second transfer characteristic, taking this reduction of con-

trast into account, is shown as a dotted line. The slope or gamma of the straight part of these characteristics is 2.4 and 2.6 for cathode drive and grid drive, respectively. It is not possible to vary this slope appreciably by gun design changes. The gamma of the signal can be modified in the video amplifier and, of course, should be adjusted to provide the desired over-all gamma.

The expected life of a theater projection kinescope is an important characteristic. Although there is relatively little actual operating experience, simulated life tests indicate that an average life expectancy of 500 hr is possible.

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1. See "Theater Television Bibliography," *Jour. SMPE*, vol. 52, pp. 268–272, Mar. 1949.
2. U.S. Pat. 2,273,801, Feb. 17, 1942.
3. *RCA Rev.*, vol. 6, no. 1, pp. 5–11, July 1941.
4. W. Epstein and L. Pensak, "Improved cathode-ray tubes with metal backed luminescent screens," *RCA Rev.*, vol. 7, pp. 5–11, Mar. 1946.
5. O. H. Schade, "Electrooptical characteristics of television systems," *RCA Rev.*, vol. 9, nos. 1–4, pp. 5–37, 245–286, 490–530 and 653–686; Mar., June, Sept. and Dec. 1948.

Installation of Theater Television Equipment

By E. Stanko and C. Y. Keen

Recent initial installations of the RCA PT-100 Theater Television System are described. Problems encountered in these installations and their practical solution are discussed. Now that the first commercial Theater Television Systems have been installed in a number of representative theaters, the experience acquired at these installations will be valuable in reducing the installation of theater television equipment to a routine procedure, comparable to the installation of sound motion picture equipment. Procedures followed in making these initial installations are described, beginning with the preliminary theater survey to the final installation check and adjustment before projecting a picture on the screen, including service and maintenance problems.

Preliminary Theater Survey

Before an installation of theater television equipment is made in any theater, certain facts about the theater must be known. One of the most important items to be determined by the survey is the location of the equipment, especially the projector unit. The PT–100 System Projector employs a Schmidt-Type Optical System with a correction lens which is limited in projection "throw" to a definite operating range.

Figure 1 shows the operating range of the optical system. There are three variables:

1. Picture size,
2. Kinescope raster* size, and
3. Projection throw from projector to screen.

So far all of the initial installations have been made in balcony-type theaters, where the projector is mounted at the front face of the balcony or in the front part of the balcony structure.

The preliminary survey includes an elevation outline plan of the theater with dimensions so that the three variables shown on the chart can be resolved and the position of the projector and screen and screen size, determined.

Theater plans are obtained where possible and are carefully examined so that the theater exhibitor can be advised how to proceed with the installation.

The survey also determines the location of the control racks in the projection booth and the location of the 80-kv high-voltage power supply unit, and includes information that will be required to solve any unusual problems in connection with the installation of the equipment.

Presented on October 20, 1950, at the Society's Convention at Lake Placid, N. Y., by E. Stanko and C. Y. Keen, RCA Service Co., Inc., Camden, N. J.

**Raster* is defined as the illumination caused by the scanning lines on the cathode-ray screen when no television picture signal is being received. Picture size is slightly smaller due to blanking interval.

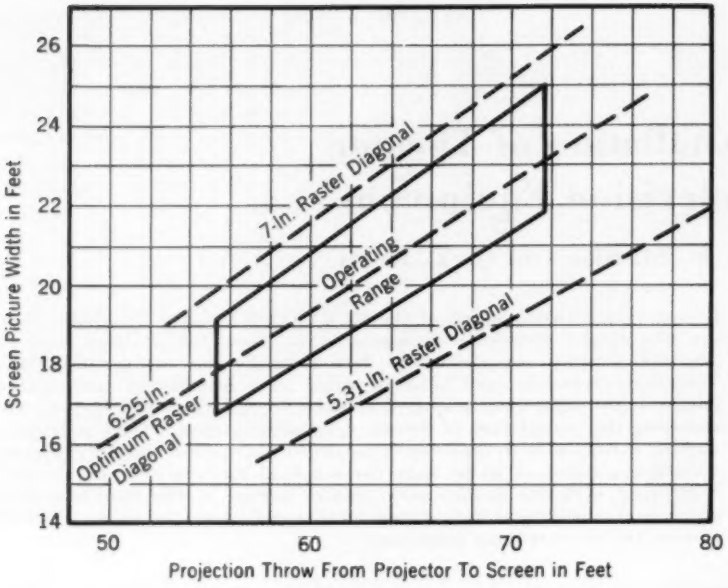


Figure 1.

Antenna Surveys

There are several means for bringing a television program to the theater. Video line facilities, consisting of coaxial cable or an equalized pair, is one method. Point-to-point transmission by microwave relay equipment is another method. "Off-the-air" pickup on the present television channels is still another method.

The PT–100 equipment is designed to receive programs by any one or all of these methods.

If "off-the-air" pickup is a requirement, it may necessitate special antenna facilities. In this case, at the request of the theater exhibitor, an antenna survey is made with the use of field-measuring equipment to determine the possibilities of obtaining an acceptable "off-the-air" signal and prepare installation instructions and specifications for an antenna installation suitable for an electrical contractor to use in order to insure getting the best possible signal obtainable at the theater location. "Off-the-air" program pickup is not generally considered to be an entirely satisfactory means of providing theater television programs, as the picture quality obtainable is, in most cases, below the performance possible with the PT–100 equipment. Figure 2 shows an antenna survey crew ready to make a field strength survey.

Installation of the PT–100 Equipment

Installation of this equipment can be divided into five principal operations. (Figure 3 shows the PT–100 Exhibitors Installation Instructions.)

1. Installation of the projector,
2. Installation of projection-booth rack equipment,
3. Installation of the high-voltage supply unit,
4. Electrical connection of equipment units,
5. Hanging the screen.

Installation of the Projector (*Figs. 4–8*).

The PT-100 System Projector is supported on legs at its center of gravity and can be pivoted in a vertical direction ±10°. Four bolts are used in each supporting leg to secure the projector to a supporting plate or steel structure which must be provided by the theater. The projector weighs 400 lb. The location of the projector, as determined by the preliminary theater survey and the construction of the theater, will determine how it is to be mounted.

In several of the initial installations of this equipment the projector was mounted with the legs horizontal. Several other installations were made with the legs mounted vertically. The method of mounting will vary in different theaters although some degree of standardized practice may be evolved from the experience gained with the first installations.

If the projector is mounted on the front face of the balcony it will require a supporting steel framework secured to the balcony steel structure with a flat surface to which the legs are bolted.

When the legs are mounted in the horizontal position, care must be taken to be sure that the supporting structure allows for some adjustment in the horizontal plane to insure that the optical axis of the projector is centered on the screen which is centered with the theater center line.

If the projector is mounted with the legs vertical it is usually easier to adjust it so that the optical axis is centered.

One method of mounting the projector that has some practical advantages utilizes two I beams projecting from the front of the balcony, which are secured to the balcony main I-beam truss and, further back, to the balcony steel structure in a cantilever arrangement.

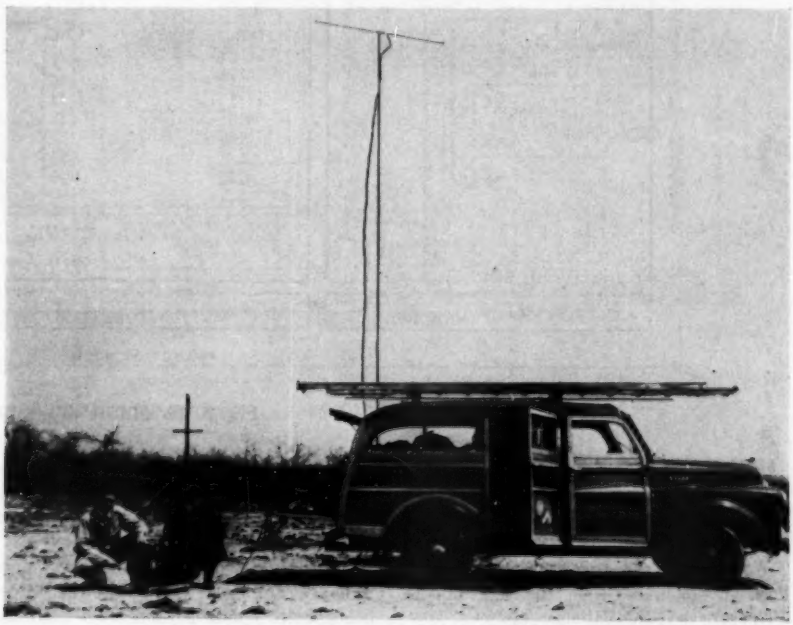


Fig. 2. An antenna survey crew ready to make a field strength survey.

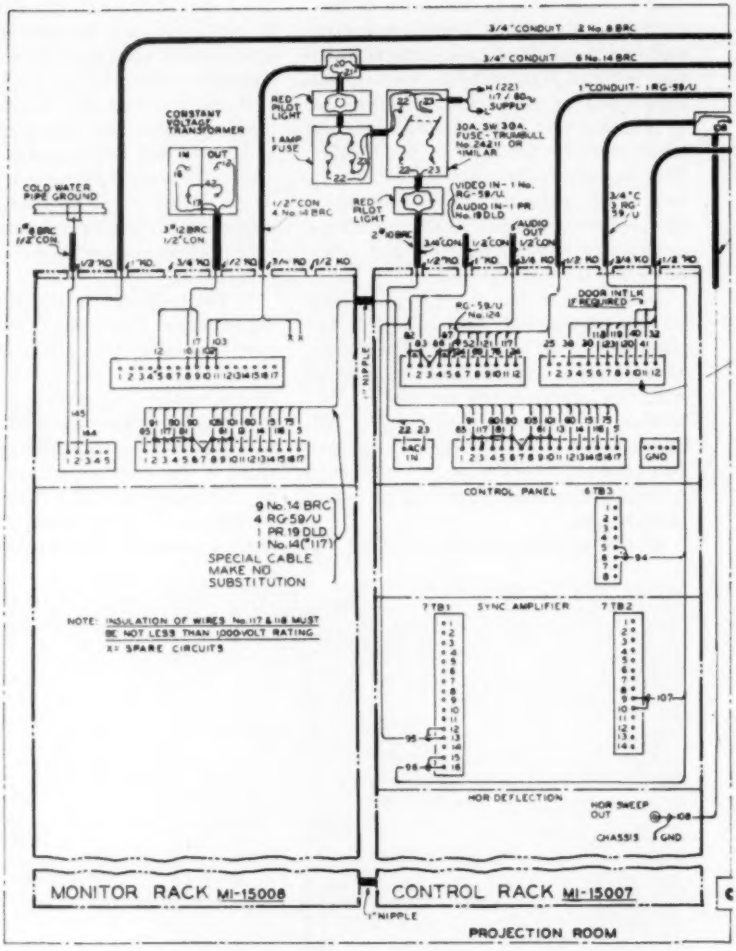
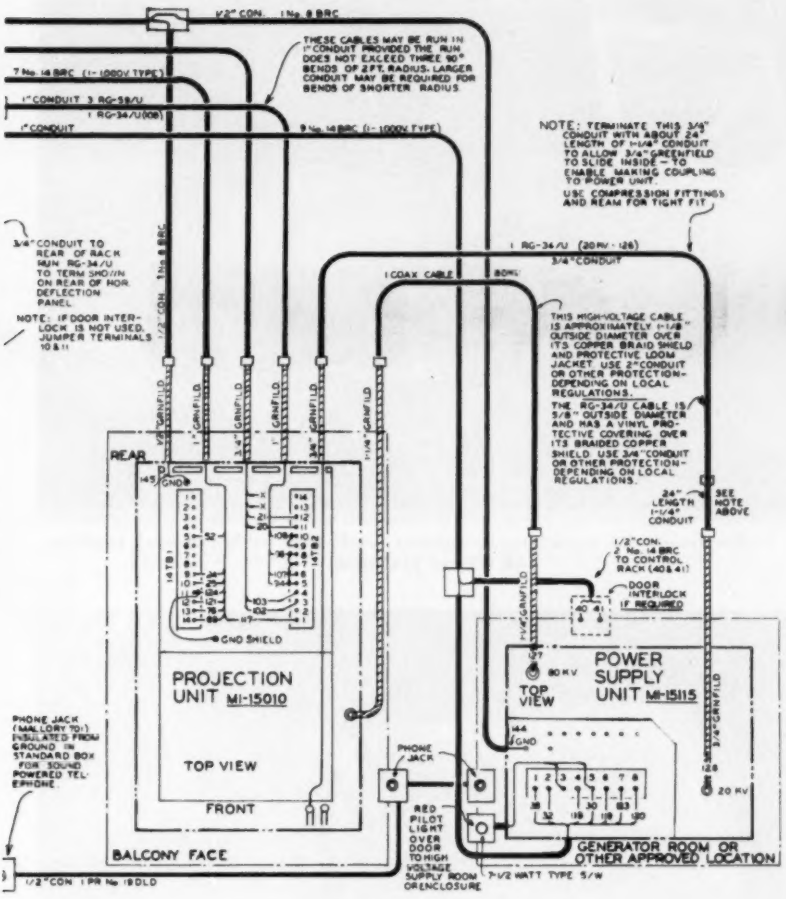


Fig. 3. Exhibitor's installation

The I beams are separated sufficiently to allow the projector legs to be mounted vertically on a plate which is bolted across the bottom of the I beams at the required distance to provide about one foot of space between the rear of the projector and the balcony face.

Provision must be made in any method of mounting so that the mounting structure does not interfere with the high-voltage cable connection to the barrel or the wiring entering the top rear conduit plate.

A servicing platform must be provided on the right side of the projector, the floor of which is on a level with the bottom of the legs when they are in the vertical position.


1/2" CON. 1 No. 8 BRC
THESE CABLES MAY BE RUN IN 1" CONDUIT PROVIDED THE RUN DOES NOT EXCEED THREE 90° BENDS OF 2FT. RADIUS. LARGER CONDUIT MAY BE REQUIRED FOR BENDS OF SHORTER RADIUS
7 No. 14 BRC (1-1000V TYPE)
1" CONDUIT 3 RG-59/U
1 RG-34/U(100)
1" CONDUIT
9 No. 14 BRC (1-1000V TYPE)
NOTE: TERMINATE THIS 3/4" CONDUIT WITH ABOUT 24" LENGTH OF 1-1/4" CONDUIT TO ALLOW 3/4" GREENFIELD TO SLIDE INSIDE — TO ENABLE MAKING COUPLING TO POWER UNIT.
USE COMPRESSION FITTINGS AND REAM FOR TIGHT FIT
3/4" CONDUIT TO REAR OF RACK RUN RG-34/U TO TERM STRIP IN REAR OF HOR. DEFLECTION PANEL
NOTE: IF DOOR INTERLOCK IS NOT USED, JUMPER TERMINALS 10 & 11
1/2" CON. 1 No. 8 BRC
1 RG-34/U (20 RV - 126)
3/4" CONDUIT
1 COAX CABLE
THIS HIGH-VOLTAGE CABLE IS APPROXIMATELY (1-1/8" OUTSIDE DIAMETER OVER ITS COPPER BRAID SHIELD AND PROTECTIVE LOOM JACKET. USE 2" CONDUIT OR OTHER PROTECTION-DEPENDING ON LOCAL REGULATIONS.
THE RG-34/U CABLE IS 5/8" OUTSIDE DIAMETER AND HAS A VINYL PROTECTIVE COVERING OVER ITS BRAIDED COPPER SHIELD. USE 3/4" CONDUIT OR OTHER PROTECTION-DEPENDING ON LOCAL REGULATIONS.
24" LENGTH 1-1/4" CONDUIT
SEE NOTE ABOVE
1/2" CON. 2 No. 14 BRC TO CONTROL RACK (40 & 41)
DOOR INTERLOCK IF REQUIRED
REAR
GND
GND SHIELD
PROJECTION UNIT MI-15010
TOP VIEW
FRONT
POWER SUPPLY UNIT MI-15115
TOP VIEW
80 KV
20 KV
PHONE JACK (MALLORY 701) INSULATED FROM GROUND IN STANDARD BOX FOR SOUND POWERED TELEPHONE
PHONE JACK
RED PILOT LIGHT OVER DOOR TO HIGH VOLTAGE SUPPLY ROOM OR ENCLOSURE
7-1/2 WATT TYPE S/W
GENERATOR ROOM OR OTHER APPROVED LOCATION
BALCONY FACE
1/2" CON. 1 PR No. 19 DLD

instructions for the projector.

The projection angle will vary in different theaters but should be kept as small as possible. The screen must be angled to the same degree. A good rule that has been applied to initial installations is to mount the projector as low as possible and the screen as high as possible, consistent with sight lines to the screen from the rear of the orchestra, the mezzanine or balcony, and interference of the projector with these sight lines. This can be determined from the theater plans when the preliminary survey is made.

When the distance from the balcony face to the screen is less than about 55 ft the projector may have to be mounted back two or three rows in the balcony

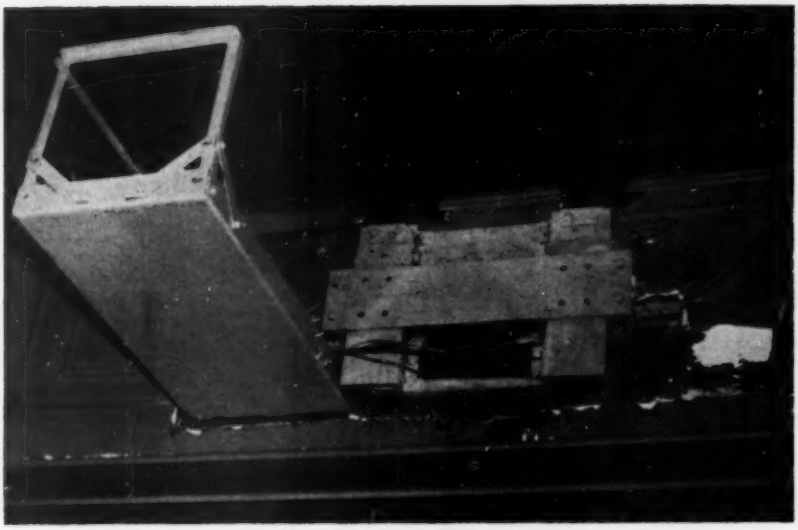


Fig. 4. Steelwork for mounting projector with legs in horizontal position, and service platform.

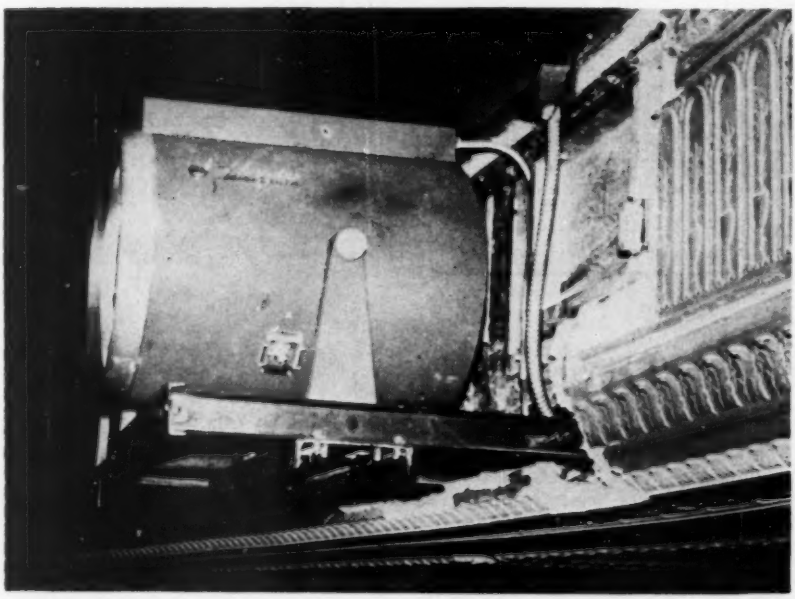


Fig. 5. Projector with legs mounted vertically on balcony steel framework.

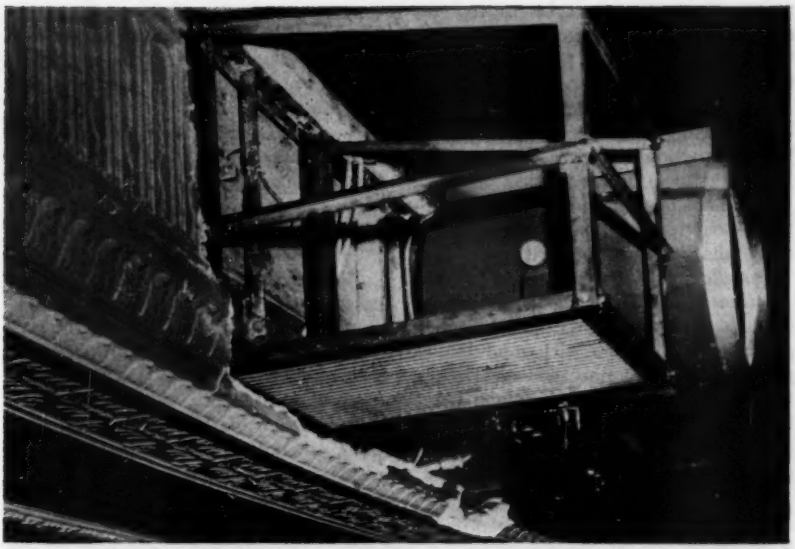


Fig. 6. Projector mounting with service platform, side view.

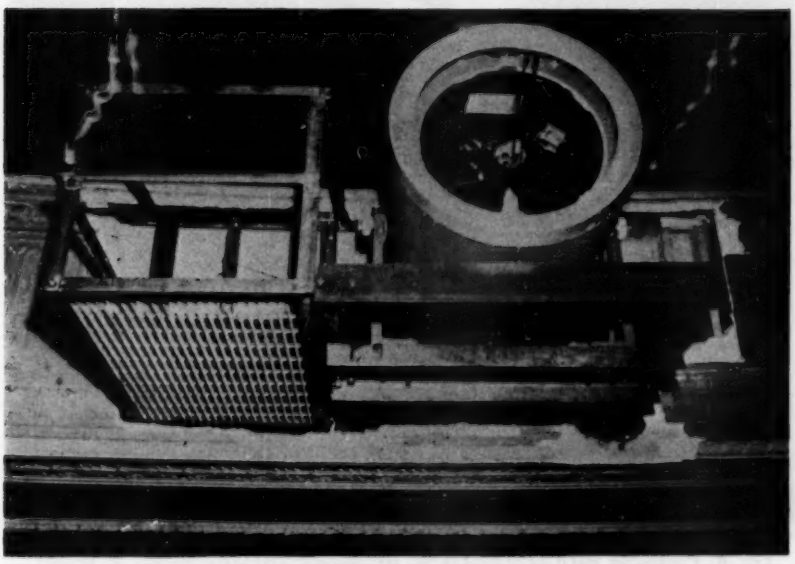


Fig. 7. Projector mounting, front view.

unless the screen can be moved far enough back on the stage to come within the operating range of the projector optical system.

Mounting the projector back in the balcony will probably require some theater constructional changes.

Several ideas for mounting the projector have been proposed for stadium-type theaters, but none have been tried in installations as of this writing.

Installation of Projection Booth Rack Equipment (*Fig. 9*). The booth equipment consists of two racks 63 in. high which are fastened together with conduit nipples and interconnected electrically through the top conduit nipple. These are similar to sound equipment racks and have conduit knockouts at the top of each rack.

It is desirable to mount the racks so that they are at a right angle to the front wall of the booth and adjacent to an observation port so that the screen can be observed when operating the controls.

A voltage-regulator transformer mounted at some convenient location in the booth or adjacent to the booth, the main power switches, pilot lights and fuse box comprise the balance of the PT–100 System Booth Equipment.

Booth space requirements in a few cases presented the only problem encountered in the installation of the rack equipment. In these instances space was made available by rearrangement of booth equipment.

Installation of the High-Voltage Supply Unit. Some problems have been encountered in the installation of the high-voltage supply unit.

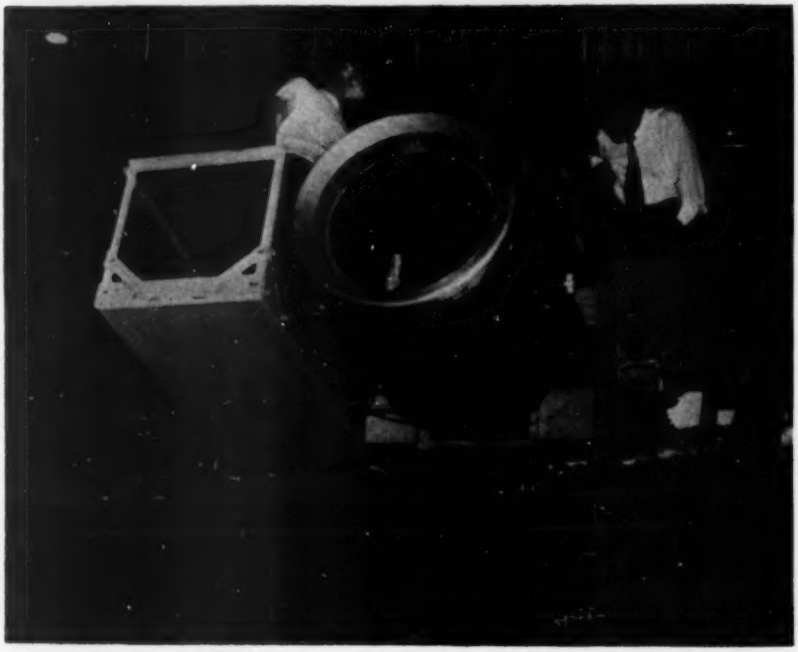


Fig. 8. Projector with horizontal leg mounting showing access to barrel from top.

As yet there is no provision in the National Electrical Code covering the installation of a unit of this type in theaters. Local rulings in several cities have required the unit to be placed in an enclosure separate from the projection booth with a door supplied with an electrical interlock switch which will turn off the supply when opened. Provision for this was anticipated in the equipment design.

Generally, it is desirable to locate this unit as near the projector as practicable to keep the 80-kv cable as short as possible. In some cases it has been located in a space under the balcony. The two high-voltage connectors (80-kv and 20-kv) are made up at the time of installation with a complete kit of materials furnished each installation.

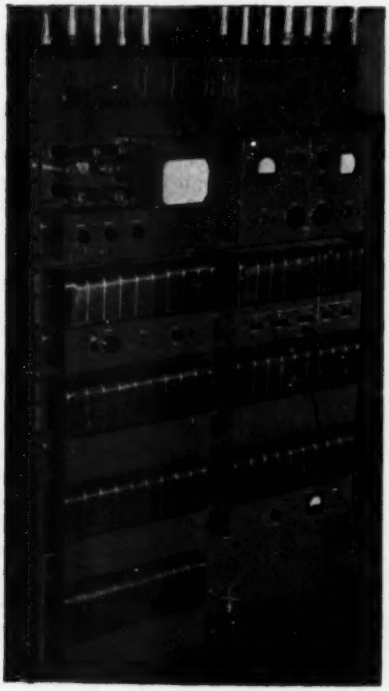


Fig. 9. Installation of Projection Booth Rack Equipment.

A small chain hoist provided by the theater is installed above the high-voltage supply unit to raise the assembly part way out of the oil for service access. The rectifier tubes and voltage-regulator tube are accessible from the top of the unit by raising a smaller part of the assembly making it unnecessary to raise the complete assembly to change tubes.

Electrical Interconnection of Equipment Units. The exhibitor's installation instructions furnished with the PT–100 include a complete wiring diagram with conduit sizes and all details required by an electrician to wire the equipment (see Fig. 3). In many respects the wiring is similar to theater sound equipment and follows established theater practice. The wiring specifications conform to the National Electrical Code wherever it applies. This provision will generally meet all local regulations as well.

Special instructions and assembly drawings are also given in the installation instructions for making up the high-voltage 80-kv connectors and 20-kv connector.

Installation of the Screen. At the present time perforated beaded screens are used for theater television projection, but the ultimate objective is to provide a screen which will satisfy the requirements of theater television and motion picture projection with one screen. Such a screen is in prospect of realization.

The screen must be located to provide a throw distance from the projector which will fall within the operating range of the PT–100 Optical System, as shown on the chart in Fig. 1.

Since practical considerations may require that the projector be located at the face of the balcony, it may be necessary to locate the theater television screen in front of or behind the present motion picture screen to bring the throw within the operating range of the system.

This presents some problems and in a

few cases has required the use of separate speakers for the theater television audio program.

Another problem was posed by the requirement of tilting the screen an amount equal to the projection angle due to the short depth of focus in the extremely "fast" optical system used in the PT–100 system.

These problems have been resolved without much difficulty in installations to date.

The screen must, of course, be masked to provide sharp picture edges. The angle of projection and the tilt of the screen and its location are all calculated in advance of the installation from the data obtained in the preliminary survey.

Installation Check and Operation

A very definite procedure has been established to check and adjust the equipment in an orderly step-by-step routine when the installation is completed and power is ready to be turned on.

This is done by a field engineer who has received previous training and is provided with the required equipment to perform this operation.

One of the important checks made on the equipment prior to installing the 7NP4 Kinescope is a step-by-step procedure to be sure that the kinescope protection circuits are functioning correctly.

When the equipment has been thoroughly checked and all adjustments made, the projectionists are given instructions in operation techniques.

Proper operation of the equipment is not difficult and in many respects parallels operation of a home television receiver. Projectionists have done an excellent job on this in the few locations involved so far.

Recently, a group of projectionists selected by the I.A.T.S.E. from practically every state in the Union were given an intensive course of television instruction in Camden, and all had an opportunity to operate the PT–100 equipment set up especially for the purpose in the RCA Engineering Laboratory Theatre.

Service and Maintenance

In any electronic or mechanical equipment there is always the problem of maintaining performance at certain predetermined standards.

Theater television equipment, due to its complexity in comparison with sound motion picture equipment, requires more attention in several respects to insure optimum performance.

There are over 100 tubes in the PT–100 Theater TV System. The average sound motion picture equipment has only about 20 tubes.

While the PT–100 equipment has been carefully designed for stability of operation consistently over long periods, some service operations must be performed by skilled engineers at periodic intervals to insure consistently top performance.

High voltages applied to the 7NP4 Kinescope could cause serious damage to the tube if the protection circuits did not function properly. These tubes are comparatively expensive, therefore periodic checks must be made in the protection circuits with proper test equipment to be sure that the correct circuit constants are always maintained. Pulse forms and amplitudes must be checked periodically with an oscilloscope suitable for this work and adjustments made if required.

The projector mirror and correction lens X-ray plate combination must be cleaned periodically. This requires careful technique with cleaning solutions developed especially for these surfaces. For example, the cleaning solution used on the mirror cannot be used on the lens surface. Service procedures are being formulated and will soon become routine.

Close coordination between the RCA Theater Equipment Engineering Group, responsible for the development and de-

sign of the PT–100 Equipment and the Technical Products Service Group of the RCA Service Company, resulted in incorporating many features in the equipment to make installation problems less difficult and expensive, and to facilitate service and maintenance operations.

Test Equipment

While many troubles in television equipment can be diagnosed by symptoms appearing on the picture screen, it is generally necessary to use an oscilloscope to trace them down in the suspected circuits.

It is necessary to use an oscilloscope that will give a true picture of the wave forms in any part of the circuits. The Type–58 or –79 Oscilloscope is used by the RCA Field Engineers for this purpose. Some of the less expensive "scopes" which are suitable for home television service work are not suitable for theater television equipment. Usually these less expensive instruments are designed for high sensitivity in the vertical amplifier at the expense of wide band response and they have other deficiencies which rule out their use for theater television equipment although they may be entirely satisfactory for checking home television receivers.

A high-resistance voltmeter is also a requirement. The 165A VoltOhmyst is used for this purpose. An instrument of this type has been found to be essential in checking this equipment.

A portable synchronizing and grating generator for field use is now under development. This instrument will furnish a suitable video signal to test the PT–100 Equipment when other signals are not available. Other test equipment is made available when required.

Discussion

HENRY ROGER: Did Mr. Stanko say it would be simpler to use rear projection on a translucent screen? I presume that you may get higher field intensity.

OTTO H. SCHADE: I think you are perfectly correct in assuming that that is possible. The normal light gain of a beaded screen is not very high—in the order of 2 or 2½. With a properly designed rear-projection screen of the lens type, you can get gains as high as 15 if the viewing angle from the front isn't too wide. Such screens are very expensive. They have to be made very precise and considerable space must be provided behind the screen for the projection distance. If the theater were laid out for such projection requirements, then it might pay to look into this situation. I think there are some rather early papers in the art. I remember a German paper reporting actual gains of the order of 12—that is, the intensity was 12 times that obtained from a purely diffuse reflecting screen.

MR. ROGER: I believe there is one disadvantage with translucent screens, and that is if the projection is in line with the eye of the observer, you get a hot point; but I believe that this can be overcome by mounting the projector slightly lower.

MR. SHADE: The type of screen which I mentioned as a lens screen avoids that completely. It is a structure of small lenses similar to a Fresnel lens directing all the rays from the sides as well as the center of the screen into a certain angle where the seats are. You can design it so that the intensity distribution in this viewing field is completely uniform. A normal translucent screen has no such means. It acts, for example, like a frosted glass, which has a very definite lobe (like an antenna) producing a hot spot in the center and much lower intensity at the sides. By putting a large condenser lens behind it, you can direct the side rays toward the center and therefore create a small area where the screen brightness is uniform. A lens screen is designed to widen this angle over a wider area without having the loss due to frosting the screen which absorbs light and scatters it vertically as much as horizontally. The lens system can be made to keep the vertical scattering extremely small and thus concentrate the entire light energy into the desired viewing space and in that manner raise the effective brightness. Lens screens can also be designed for front projection, but as I said, a lens screen is very expensive compared to normal low-gain screens.

Standards

Splices for 16-Mm and 8-Mm Film

THESE PROPOSED American Standards, developed by the 16-Mm and 8-Mm Motion Pictures Committee, appear on the following pages. They are published here for trial and criticism for a period of ninety days. Please forward any comments to Henry Kogel, Staff Engineer at Society Headquarters, by July 1, 1951.

For many years the standards for splices have shown both a diagonal splice with a 0.070-in. overlap and a straight splice with a 0.100-in. overlap. It is presumed that the diagonal splice was narrower so that it would not encroach on the perforations. These dimentions were specified in Chart 12 of Z22–1930 and repeated in 1941 in Z22.24 and Z22.25. Actually, however, the dimensions of the straight splice were first established in 1924 when 16-mm equipment was introduced. Many thousands of splicers making splices with these dimensions have been manufactured and used. When splicers for 8-mm film were introduced in 1932, the same 0.070-in. and 0.100-in. overlaps for diagonal and straight splices were specified.

For twenty years these dimensions have been retained as new splicers came on the market, even though a great deal of experimental work was being conducted in an effort to improve splices and lengthen their life during projection.

In January, 1944, Subcommittee C of the American Standards Association's Z52 War Committee on Photography and Cinematography was appointed to handle standards relating to 16-mm laboratory practice. One of the first projects of this subcommittee was to specify the type of splice that should be used for 16-mm release prints. The discussion showed that there was little agreement among the laboratories. Some preferred narrower splices because they are less conspicuous on the screen. It was stated that, contrary to former beliefs, wide splices were more susceptible to failure than narrow ones. Several members said that they were using splices that were less than 70-mils wide and had found them quite satisfactory. It was then agreed to make the 0.070-in. overlap a maximum inasmuch as it was desired to secure splices with as small an overlap as possible. It was then decided to write a new standard covering diagonal and straight splices.

Later the title of the proposed standard was changed to limit the splices to processed film because the suitability of the splices for raw stock had not been considered by the committee. The final War Standard, Z52.20–1944, was approved May 29, 1944, by the American Standards Association.

This action resulted in the existence of two standards for straight splices: the original 0.100-in. splice from Z22.24–1941 and Z22.25–1941, and the new 0.070-in. splice in Z52.20–1944. It was realized at the time that careful comparative

tests would eventually be required in order to determine which splice was superior. If it were decided to carry over into peacetime the 0.070-in. splice, it would be necessary to rebuild all the existing tools for amateur splicers, which would involve considerable expense to the industry because of the many splicers for 0.100-in. splices on the market.

Consideration of Dual Standards

The desirability of continuing the two standards for splices was considered when Committee Z22 of the American Standards Association reviewed the War Standards in October, 1945. At this meeting, and at subsequent meetings, the need for having standards for splices was questioned, but the committee decided that such standards were of value to the industry. Eventually, the question was referred by Z22 to the Standards Committee of the Society, and a subcommittee was appointed, under the chairmanship of W. H. Offenhauser, Jr., to review the situation.

Meanwhile, the suggestion had been made that the 0.100-in. splice be designated the amateur splice and that the 0.070-in. be the professional or laboratory standard. This suggestion was discussed by the subcommittee, and it was agreed that the standard should prescribe good commercial practice, as well as a splice that would be practicable for the amateur.

The relative merits of symmetrical versus unsymmetrical splices were also discussed, but it was decided that both diagonal and straight splices would be shown symmetrical with respect to the included perforation. Finally, although it was brought out that the 0.070-in. splice would be difficult for the amateur to perform because of the more precise control of hand scraping required, it was voted that the 0.070-in. straight splice be standardized for a trial of one year. During that period, data would be collected so that a review could be made and a final decision reached.

This decision of the subcommittee was reported to the Standards Committee at a meeting on February 20, 1946. Although one member reported at that time that the narrower splice did not last as long in projection as the 0.100-in. splice, it was decided to publish the standard calling for the narrower splice and to collect more information during the trial period of one year.

When the report on splices was presented to the Society on May 8, 1946, the following test results was submitted to Mr. Offenhauser: Of 45 loops of film, each containing one 0.100-in. and one 0.070-in. splice and run in a projector until one of the splices broke, 40 loops broke first at the 0.070-in. splice and only 5 broke first at the 0.100-in. splice. These tests were run by two different departments of the same company, and included three projectors and splices made by several different operators. A third group ran 6 loops containing two splices of each width. The average life of the 0.070-in. splice was half that of the 0.100-in. splice.

Conclusions of Tests

These conclusions were confirmed later with splices made on an expensive precision splicer of the 0.070-in. type. Seven loops were made with one 0.070-in. precision splice and one 0.100-in. splice. All broke at the 0.070-in. splice first. In most cases, nevertheless, the life of the weaker 0.070-in. splice was probably adequate for either amateur or professional use. Such might not have been the case, however, if an ordinary hand splicer had been employed since most operators have considerable difficulty scraping the narrow splice. Bebecause the strip of film between the perforations and the cut end of the film is only 0.010-in. wide, it is difficult to remove all the emulsion without damaging the film. In addition, shrinkage of

the film reduces this width still further and makes the scraping operation even more difficult.

From the foregoing tests, it is quite apparent that the wide splice was stronger despite its greater resistance to smooth bending of film around loops, rollers and sprockets.

Comments After Publication

The proposal of the subcommittee was published in the July, 1946, JOURNAL. It was simpler than previous standards because nonessential dimensions were omitted. Although only sound film was shown, it was stated that splices for silent film would be the same, A curved splice, included in the War Standard, was dropped because no one expressed interest in it. Comments were invited, particularly on the relative desirability of the 0.070-in. splice compared with the 0.100-in. splice, and on symmetrical versus unsymmetrical splices.

Although the response was rather small, a number of interesting suggestions were offered. The suggestions fell into two distinct groups: first, those concerned with splices made in processing laboratories by professionals, usually in negative or other preprint material; and second, those concerned with splices made in reversal originals or release prints.

Of the first group, a proposal by Joseph V. Noble of DeFrenes & Company Studios called for an invisible 0.016-in. frameline splice in the width of the film devoted to the picture area, with an overlap of 0.079 in. along both edges of the films. In addition, John S. Carroll listed the advantages of the unsymmetrical Griswold "negative" splice, and advocated increasing its width from 0.0625 in. to 0.070 in. for greater strength. He did not recommend it for release prints, however, because of its poorer mechanical properties. G. A. Chambers recalled the successful use of 0.070-in. splices at the Anacostia laboratory and recommended them for laboratories but not for the amateur.

The group favoring the retention of the 0.100-in. overlap was interested primarily in amateur splicing. Their arguments were based on the longer projection life the greater success that the amateur has in making the 0.100-in. splice, and the large investments in tools for 0.100-in. splicers.

Since the industry did not appear to be ready for the adoption of the standards outlined in the July, 1946, JOURNAL, the Committee on Standards agreed that the original Z22.24 and Z22.25 should be reaffirmed until the situation is clarified. At this point, the problem of standards for splices was referred to the 16-Mm and 8-Mm Motion Pictures Committee.

Work of 16-Mm and 8-Mm Committee

In preparing the drafts submitted herewith, the Committee noted that the old standards did not conform to modern methods of dimensioning. It was suggested, also, that sound and silent films be combined into one standard. As these changes were made, it was discovered that other alterations and additions would be desirable. For example, the splices were redrawn so that they would appear as they do on splicing blocks. Tolerances were added to cover the proper transverse alignment of the perforations and the edges of the films, and the parallelism of the edges of the two films after the splice has been made. Again the question of whether straight splices should be 0.070-in. or 0.100-in. wide was raised. For 8-mm film the 0.100-in. splice was of course preferable. When the title and wording of the 16-mm splice proposal were changed to limit it to release prints, all objections to the 0.100-in. splice were withdrawn.

Drafts of the proposals approved by the 16-Mm and 8-Mm Motion Pictures Committee were submitted to the Stand-

ards Committee in May, 1949, for balloting on the question of publication in the JOURNAL for a ninety-day period of trial and comment. In due course, this ballot was completed favoring publication at an early date. During the course of this balloting, however, various members of the 16- and 8-mm Committee raised the question of whether or not manufacturers of splicers still promoted the sale of equipment to make diagonal splices. Upon investigation, it was found that no manufacturer expects to produce equipment of this type in the future. In the light of this information, it was recommended that the diagonal splice be dropped from the proposal.

Since this was considered to be a major change from the version upon which the Standards Committee originally balloted, the ballot was withdrawn at a meeting of the Standards Committee on February 1, 1950. In subsequent balloting, completed in December, 1950, and January, 1951, the Committee approved publication of these two proposals in their present form for trial and comment.

Erratum:

W. F. Kelley and W. V. Wolfe, "Recent studies on standardizing the Dubray-Howell Perforation for universal application," *Jour. SMPTE* vol. 56, pp. 30–38, Jan. 1951.

Page 32, line 5 *et seq.*, and Fig. 1: *For* Cooke *read* Cook. This refers to Allen W. Cook who made the Ansco proposal a number of years ago.

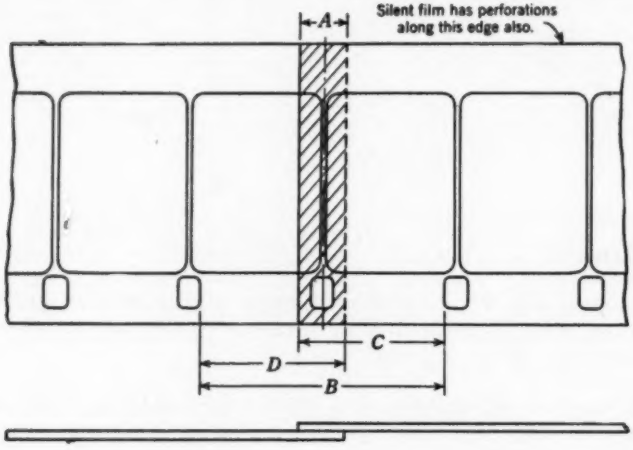
Proposed American Standard

Splices for 16-Mm Motion Picture Films for Projection

PH22.24
(Z22.24)
Revision of
Z22.24 – 1941
and
Z22.25 – 1941

P. 1 of 2 pp.

Scope. Splices made in accordance with this standard are primarily for use with films intended for actual projection, such as release prints and reversal films. It is not intended that this standard be prejudicial to the use of diagonal type splicers, nor to the use of narrower splices for professional purposes. For negatives and other laboratory films, narrower splices, sometimes with one edge on the frameline, frequently are used.



	Inches	Millimeters
A	$0.100^{+0.000}_{-0.005}$	$2.54^{+0.00}_{-0.13}$
B	$0.548^{+0.001}_{-0.001}$	$13.920^{+0.025}_{-0.025}$
C	$0.324^{+0.000}_{-0.003}$	$8.23^{+0.00}_{-0.08}$
D	$0.324^{+0.000}_{-0.003}$	$8.23^{+0.00}_{-0.08}$

NOT APPROVED

Proposed American Standard

Splices for 16-Mm Motion Picture Films for Projection

PH22.24
(Z22.24)
Revision of
Z22.24 – 1941
and
Z22.25 – 1941

Note 1. In the plan view, the splice is arranged with the perforations at the bottom in order to show them as they appear on most splicers. The splice may be made with the films turned through an angle of 180 degrees, or any other angle, but of course the emulsion surface should always be up. It is customary to scrape the top (emulsion) surface of the left-hand film and to cement this scraped area to the bottom (base) surface of the right-hand film.

Note 2. Dimension A is given a negative but no positive tolerance because narrower splices are less conspicuous on the screen and are less likely to affect the normal curvature of the film as it follows the bends in its path through cine-machinery.

Note 3. Dimension B controls the longitudinal registration of the two films being spliced. It is measured to the perforations that are most commonly used for registration on splicing blocks, and to the nearer edges of these perforations because they are edges that are generally used for the registration. This dimension is made the same as in Z22.77, Splices for 8-Mm Motion Picture Film, because many splicers are designed to accept either 16- or 8-mm film.

The nominal value of the B dimension was made 0.548 inch instead of the usual 0.550 (for unshrunk film) because the films being spliced are always shrunk to some extent. The 0.548 figure corresponds to a shrinkage of 0.36 percent, while the 0.549 and 0.547 values, permitted by the tolerances, correspond to 0.18 percent and 0.55 percent, respectively. Thus, the tolerances include the range of shrinkage ordinarily encountered when film is being spliced.

Note 4. Dimensions C and D were chosen to give a straight 0.100-inch splice that is symmetrical about the included perforation (and, therefore, the frameline) when the film is shrunk 0.36 percent. See Note 3 above.

Note 5. The width of the film at the splice shall not exceed 0.630 inch. If the film has been widened during scraping, the extra width shall be removed.

Note 6. The overlapping perforations of the two films shall not be offset laterally more than 0.002 inch.

Note 7. At the splice, the edges of the two spliced films shall not be offset laterally more than 0.002 inch, unless a difference in the lateral shrinkages of the two strips makes it impossible to maintain that tolerance. Shoulders formed by such misalignment shall be beveled after the cement has dried.

Note 8. In the plan view, the angle between the respective edges of the spliced films shall be 180 degrees, plus or minus 40 minutes. Thus, the spliced film shall be aligned to the extent that when one portion of the film is placed against a straight edge, the other portion will not deviate more than 0.006 inch (approximately the thickness of the film) in 6 inches.

Note 9. In order to prevent the appearance of a white line on the screen, the scraped area shall be 0.001 to 0.003 inch narrower than the area covered by the overlapping film. The presence of this narrow uncemented area will not shorten the life of the splice.

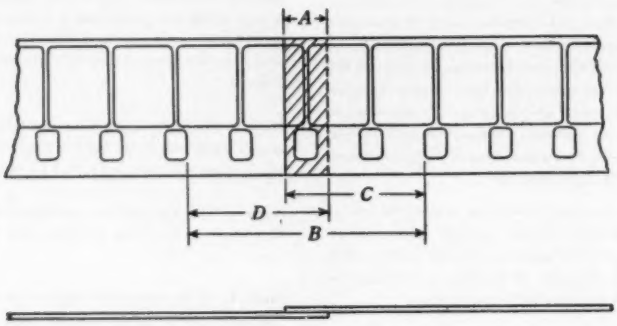
NOT APPROVED

Proposed American Standard

Splices for 8-Mm Motion Picture Films

PH22.77
(Z22.77)

P. 1 to 2 pp.



	Inches	Millimeters
A	$0.100\ ^{+0.000}_{-0.005}$	$2.54\ ^{+0.00}_{-0.13}$
B	$0.548\ ^{+0.001}_{-0.001}$	$13.920\ ^{+0.025}_{-0.025}$
C	$0.324\ ^{+0.000}_{-0.003}$	$8.23\ ^{+0.00}_{-0.08}$
D	$0.324\ ^{+0.000}_{-0.003}$	$8.23\ ^{+0.00}_{-0.08}$

Note 1. In the plan view, the splice is arranged with the perforations at the bottom in order to show them as they appear on most splicers. The splice may be made with the film turned through an angle of 180 degrees or any other angle, but, of course, the emulsion surfaces should always be up. It is customary to scrape the top (emulsion) surface of the left-hand film, and to cement this scraped area to the bottom (base) surface of the right-hand film.

Note 2. Dimension A is given a negative, but no positive, tolerance because narrower splices are less conspicuous on the screen and are less likely to affect the normal curvature of the film as it follows the bends in its path through cine-machinery.

NOT APPROVED

Note 3. Dimension B controls the longitudinal registration of the two films being spliced. It is measured to the perforations that are most commonly used for registration on splicing blocks, and to the nearer edges of these perforations because they are the edges that are generally used for the registration. This dimension was made the same as in Z22.24, Splices for 16-Mm Motion Picture Film, because many splicers are designed to accept either 8-mm or 16-mm film.

The nominal value of the B dimension was made 0.548 inch instead of the usual 0.550 (for unshrunk film) because the films being spliced are always shrunk to some extent. The 0.548 figure corresponds to a shrinkage of 0.36 percent, while the 0.549 and 0.547 values, permitted by the tolerances, correspond to 0.18 percent and 0.55 percent, respectively. Thus the tolerances include the range of shrinkage ordinarily encountered when film is being spliced.

Note 4. Dimensions C and D were chosen to give a 0.100-inch splice that is symmetrical about the included perforation (and therefore the frameline) when the film is shrunk 0.36 per cent. See Note 3.

Note 5. The width of the film at the splice shall not exceed 0.317 inch. If the film has been widened during scraping, the extra width shall be removed.

Note 6. The overlapping perforations of the two films shall not be offset laterally more than 0.002 inch.

Note 7. At the splice, the edges of the two spliced films shall not be offset laterally more than 0.002 inch unless a difference in the lateral shrinkages of the two strips makes it impossible to maintain that tolerance. Shoulders formed by misalignment shall be removed after the cement has dried.

Note 8. In the plan view, the angle between the respective edges of the spliced films shall be 180 degrees, plus or minus 40 minutes. Thus, the spliced film shall be aligned to the extent that when one portion of the film is placed against a straight edge, the other portion will not deviate more than 0.006 inch (approximately the thickness of the film) in six inches.

Note 9. In order to prevent the appearance of a white line on the screen, the scraped area shall be 0.001 to 0.003 inch narrower than the area covered by the overlapping film. The presence of this narrow uncemented area will not shorten the life of the splice.

NOT APPROVED

69th Semiannual Convention

AFTER THE ADVANCE NOTICE of the Convention, listing ten technical sessions, went out to Society members on March 9, two sessions were added to make the Tentative Program which has also been mailed. The Tentative Program contained 56 papers and 7 committee reports. Additional copies of the Tentative Program are available from Society headquarters.

Adjustments, indicated as likely at JOURNAL *press time, have been taken into account to show below the transfer of the* Screen-Viewing Factors *and the* Film Projection Symposiums *to Wednesday, concurrent with Wednesday's* High-Speed Photography Sessions, *and to show that Thursday afternoon will probably be used to take up some of the papers shown in the heavy sessions in the Tentative Program.*

APRIL 30—MAY 4

Monday afternoon	Film and Processing
Monday evening	Motion Picture Techniques
Tuesday morning	Television Recording and Reproduction
Tuesday afternoon	Television Session — and Tour of the Bell Telephone Murray Hill Laboratories
Tuesday evening	Television and Motion Picture Production
Wednesday morning	High-Speed Photography
" "	Screen-Viewing Factors Symposium
Wednesday afternoon	High-Speed Photography
" "	Film Projection Symposium
Thursday morning	High-Speed Photography
Thursday afternoon	See Final Program
Friday morning	Magnetic Recording
Friday afternoon	Sound Recording

Each session will open with a motion picture short. A luncheon will open the Convention on Monday noon, and a banquet and dance will be held Wednesday evening. Complimentary tickets to selected Broadway motion picture theaters will be issued to registered members and guests.

Any reader who did not receive the Advance Notice can get a copy from Society headquarters or he can write for reservations (mentioning the SMPTE) direct to: Front Office Manager, Hotel Statler, 7th Ave., 32d and 33d Sts., New York 1.

Also, readers of subscription copies of the JOURNAL need only send a postal to Society headquarters to get a copy of the Tentative Program.

SPADEWORK

Bill Kunzmann, Convention Vice-President, notes that the Papers Committee, listed in the JOURNAL last month, has turned in a fine job. He urges that all who have been asked to help with work assigned to the following chairmen dig in with a will. With their help, all Convention machinery will function smoothly, thanks to these chairmen:

Hotel and Transportation — H. D. Bradbury
Local Arrangements — E. M. Stifle
Luncheon and Banquet — W. B. Lodge
Membership and Subscriptions — L. E. Jones
Motion Pictures — Emerson Yorke

Public Address — H. B. Braun
Publicity — Harold Desfor with Leonard Bidwell and Harry Sherman
Projection, 35-mm — H. E. Heidegger, with officers and members of New York Projectionists Local 306
Projection, 16-mm — T. P. Dewhirst
Registration and Information — E. R. Geib with P. D. Reis, G. H. Gordon and E. A. Hungerford
Television — C. L. Townsend
Ladies' Registration — Mrs. E. M. Stifle, Hostess, with Mrs. E. I. Sponable, Mrs. Herbert Barnett and Mrs. O. F. Neu

Engineering Activities

STANDARDS COMMITTEE MEETING

At its annual meeting held in the last week of January, 1951, the Standards Committee, under the Chairmanship of Frank Carlson, had a very full and fruitful session. The first order of business was a review of the status of all Proposed Standards currently before the Committee, as outlined below:

Approved by Standards Committee and PH22

Cutting Dimensions for 32-Mm on 35-Mm Motion Picture Negative Raw Stock, PH22.73
Zero Point for Focusing Scales on 16-Mm and 8-Mm Motion Picture Cameras, PH22.74
Mounting Threads and Flange Focal Distances for Lenses for 16-Mm and 8-Mm Motion Picture Cameras, PH22.76

Approved by Standards Committee for Submittal to PH22

Sound Transmission of Theater Projection Screens, PH22.82

Approved by Standards Committee for Preliminary Publication in JOURNAL

A and B Windings of 16-Mm Raw Stock Film, PH22.75; published January, 1951
Edge Numbering of 16-Mm Motion Picture Film, PH22.83; published January, 1951
Splices for 16-Mm Films for Projection, PH22.24; published in this JOURNAL
16-Mm Motion Picture Projection Reels, PH22.11; published February, 1951
Dimensions for Projection Lenses, Medium Prefocus Ring Double-Contact Base-Up Type, PH22.84; published February, 1951
Dimensions for Projection Lamps, Medium Prefocus Base-Down Type, PH22.85; published, February, 1951
Splices for 8-Mm Motion Picture Film, PH22.77; approved subsequent to meeting and published in this JOURNAL.

Edge Guiding of 16-Mm Films. The question of edge guiding was then explored in view of an apparent inconsistency in Society policy. In this regard recent Standards, PH22.7-1950, and PH22.8-1950, do not specify a single guided edge, stating that either edge may be used and giving the arguments for each; however, other Standards, PH22.15, PH22.16 and PH22.41, do specify the guided edge. The first two deal entirely with emulsion position and hence the Committee voted to revise these standards, deleting specification of guided edge. However, PH22.41, Sound Records and Scanning Area of 16-Mm Sound Motion Picture Prints, presents several problems:

1. The present tolerances may be dependent on the specification of the guided edge.

2. Advent of 32-mm film as source of 16-mm release prints and consequent slitting problems may require such specification. It was, therefore, agreed that the Engineering Vice-President would refer this to the Sound Committee (to be reviewed by the 16-Mm and 8-Mm Committee) for further study with the directive to revise if this can be done without degrading the present standard.

Glossary. The desirability of compiling

a glossary of technical terms peculiar to the motion picture industry was readily agreed upon. The discussion centered rather on practical methods of achieving this, inasmuch as attempts had been made in the past without appreciable success. It was finally agreed that each committee chairman would be asked to draw up a list of terms he considered vital for inclusion in such a glossary. This could be readily achieved and would provide a basis for further work. It might then be possible, after some discussion, to get immediate agreement on a definition for 75–90% of the terms. A glossary would then exist and, although incomplete, be at least better than nothing at all and a good starting point for further work.

International Standards. Fred Bowditch, Engineering Vice-President, gave a brief history of the International Standards Organization (ISO), noting that the International Standards Association dissolved at the onset of the second World War and that the ISO was formed as an adjunct to the UN. The American Standards Association (ASA) is the United States representative in the ISO and as such holds the Secretariat of Technical Committee 36 (TC36) for Motion Pictures. This means that sectional committee PH22 of ASA should rightfully be handling ISO questions, but in effect, as sponsor of PH22, the final responsibility belongs to SMPTE. A meeting of TC36 had been proposed for this coming summer in Geneva, but the consensus was that in the absence of a specific agenda of recognized importance, there was no real justification for such a meeting now. As Secretariat, ASA had distributed 40 American Standards in 1948 and proposed they be made International Standards. Comments on these have been received from several countries and require additional correspondence on our part. In view of projected ISO meetings in this country during 1952, it might be wise to begin now the preparation of specific agenda.

The ensuing discussion brought out several vital points:

1. Some of the standards submitted have since been revised.
2. The advent of low-shrink film may soon require revision of other standards.
3. Additional standards now exist which may also warrant international standardization. It was therefore agreed that all members of the Standards Committee would inform the Chairmen of those standards which they feel might be important for an International Standards Program and include along with the standard a brief review of the history and present status of each standard.

Very often, material is received from other nations with requests for comments. In such a case, it was agreed that the proper channels for such material should be from the various foreign standards institutes to ASA (PH22) then to the SMPTE Engineering Vice-President and finally to the appropriate engineering committee.

Research Projects. The Engineering Vice-President stated that he had been requested by the Board of Governors, in line with a recommendation by Clyde Keith, to prepare a list of research problems which might be used by graduate students in universities as theses projects. Such graduate research activity can well produce information of value to industry and is thus worth encouraging. He therefore emphasized his earlier written request that each engineering committee consider the preparation of a list of projects in its field, together with brief background material explaining each project.

NEW STANDARDS SOON

Three proposed American Standards are now on their last lap in the course of becoming Approved Standards. Having been approved by the Engineering Committee, the Standards Committee, ASA Sectional Committee PH22 and the Society Board of Governors, they are now awaiting final approval by the ASA Photographic Standards (Correlating) Committee and then the ASA Standards Council. They are:

1. PH22.73, Cutting and Perforating Dimensions for 32-Mm on 35-Mm Raw Stock
2. PH22.74, Zero Point for Focusing Scales for 16-Mm and 8-Mm Motion Picture Camera
3. PH22.76, Mounting Threads and Flange Focal Distances for Lenses for 16-Mm and 8-Mm Motion Picture Cameras

BOOK REVIEW

Acoustical Designing in Architecture

By Vern O. Knudsen and Cyril M. Harris. Published (1950) by John Wiley, 440 Fourth Ave., New York 16. 404 pp. + 45 pp. appendix + 7 pp. index. 180 illus. + 8 tables. 5½ × 8¾ in. Price $7.50.

This is the most readable, useful and practical book on architectural acoustics which we have encountered. Naturally, most of the information can be found in more complete and complicated form in the Acoustical Society Journals, earlier books and other periodical literature. Such a collection, we believe, would be far too extensive and technical for the average architect and engineer (other than the acoustical engineer) to maintain or use to his advantage.

Professor Knudsen's earlier book, *Architectural Acoustics*, embracing much of his original research, furnishes fit foundation for this new and excellent collaboration. Comparison of the two in such matters as sound absorptive materials shows that many of the materials mentioned in the first book have disappeared from the market, while new ones (they generally have coined names) have been developed by a fast-moving industry even since the publication of the present book. Changes such as this can be expected in materials, methods and sound systems, but certainly, the well-presented basic information will remain useful.

The authors have designed this book primarily for architects and students of architecture, and there is no doubt that if an architect will make use of this book intelligently, he will avoid most of the glaring errors which crop up in public buildings. We suggest that Chapters 9 through 14 be read before consigning the book to a shelf. This procedure will probably arouse enough interest to make the reader do the first eight chapters, at least lightly. Chapters 1 through 8 deal largely with the physics of sound and with the nature of speech and hearing. Chapters 9 through 14 are concerned with basic design, the selection of a proper site, arrangement of rooms, control of noise both air-borne and structurally transmitted, and use of sound amplification systems. These parts together offer a fairly simple and lucid explanation of the nature and behavior of sound in its relation to architecture. Specific problems in rooms for special uses are treated in the remainder of the book. Reference may be made to these sections as the need requires.

There is a chapter on each of the following: auditoriums; school buildings; commercial and public buildings; homes, apartments and hotels; church buildings; broadcasting, television and sound-recording studios.

While this book purports to be a non-mathematical treatise, it frequently steps out of character with the sudden appearance of mathematical terms not commonly met with in architecture. These constitute the common language of the acoustical engineer or physicist but probably convey little information to the architect. However, many of the expressions given are interpreted by graphs which, if studied, will supply a fairly close answer.

Undoubtedly, complicated problems will arise where the architect may need the services of a specialist in this field, but his task will be considerably lightened and his resulting design better if he has a basic understanding of the acoustic principles underlying the form and structure being considered.

Aside from the use of this book by the architect and reader of general interest, it is recommended as a good additional reference work for engineers in the sound field. The careful listing of design procedure, the extensive collation of sound-absorbing coefficients of different materials and data on sound transmission of various constructions make the book very much worth while.—JAMES Y. DUNBAR, William J. Scully Acoustics Corp., 101 Park Ave., New York 17.

SMPTE Officers and Committees: New rosters are scheduled to be published in the April JOURNAL.

Virgil B. Sease

AFTER 33 YEARS with E. I. du Pont de Nemours & Company, Dr. Sease retired from his activities at Du Pont's Redpath Laboratory, Parlin, N.J., at the end of 1950. He has been a member of this Society since 1926. He became a Fellow in 1934, the year in which the grade of Fellow was established.

Dr. Sease joined the Du Pont Company in 1917 as a research chemist at the Experimental Station near Wilmington, Del. From late in 1917 until 1920 he was engaged in similar activity at the Delta Laboratory, Arlington, N.J., where he worked on the acetylation of cellulose. In 1920 he went to the Redpath Laboratory, Parlin, N.J., where investigations on the manufacture of photographic film were in progress. In 1925, he became director of research for the Du Pont-Pathe Manufacturing Corp., at Parlin. When this organization became Du Pont's Photo Products Dept., he moved to Wilmington in the same capacity. He became technical consultant to the department in 1942 and technical adviser in 1946. He was named director of the development section in 1947.

Dr. Sease's research on photographic emulsions included studies on precipitation conditions, the role of iodide and the nature of gelatins. He was particularly interested in grain size and in this connection worked on the formulation of developers to control graininess. He wrote a number of technical articles on photographic developments and was responsible for the development of a number of patents in the photographic field.

He was born near Leesville, S.C., in 1888. He received his B.A. degree from Newberry College in 1908, was principal of a high school in South Carolina from 1908 until going to Newberry College as an instructor in 1911. He was a fellow at Johns Hopkins from 1916 to 1917 and he received his Ph.D. from Johns Hopkins in 1917. He and Mrs. Sease now live at 1010 Berkeley Rd., Wilmington 67, Del.

New Members

The following members have been added to the Society's rolls since those published last month. The designations of grades are the same as those used in the 1950 MEMBERSHIP DIRECTORY.

Honorary (**H**) Fellow (**F**) Active (**M**) Associate (**A**) Student (**S**)

Aragones, Daniel, Partner, Managing Director, Laboratorio Cinefoto. **Mail:** Ave. Gral. Franco 426, Barcelona. (**A**)

Bennett, Norman, American University. **Mail:** 10707 St. Margarets Way, Kensington, Md. (**S**)

Bischof, Wallace F., 3524 E. Anderson Ave., Albuquerque, N. M. (**A**)

Bodnar, John, Head, International Cutting Dept., Twentieth Century-Fox Film Corp. **Mail:** 1210 Daniels Ave., Los Angeles 35, Calif. (**M**)

Bradish, Albert S., Vice-President in Charge of Production, Atlas Film Corp. **Mail:** 1526 N. Harlem Ave., River Forest, Ill. (**M**)

Bunnell, Ray F., Head, Electrical Dept., Warner Brothers Pictures, Inc. **Mail:**

900 E. Angeleno Ave., Burbank, Calif. (M)

Clayton, Vincent E., Chief Engineer, Radio Service Corporation of Utah. **Mail:** 1525 Browning Ave., Salt Lake City, Utah. (M)

Coan, Alexander D., Television Advertising, Philbin, Brandon & Sargent, Inc. **Mail:** 277 Park Ave., New York 17, N.Y. (A)

Dance, Darrell A., Chief, Technical Services Branch, Motion Picture Division, U.S. Dept. of State. **Mail:** 15 Arcadia Rd., Apt. 21A, Hackensack, N.J. (M)

Davis, Wesley J., Boston University. **Mail:** 125 Homestead St., Boston 21, Mass. (S)

de Gorter, Benjamin, Research Librarian, Technicolor Motion Picture Corp. Research Dept., 6311 Romaine St., Hollywood 38, Calif. (A)

Faris, Herbert C., General Manager, Tele Sales, Inc. 118 St. Clair Ave., N.E., Cleveland, Ohio. (A)

Fitzstephens, John J., Associate Instructor, New Inst. for Film and Television. **Mail:** 315 W. 14 St., New York 14, N.Y. (A)

Glubin, Samuel B., New Inst. for Film and Television. **Mail:** 231 Snediker Ave., Brooklyn 7, N.Y. (S)

Gomez, Miguel A., New Inst. of Film and Television. **Mail:** 23 A Ulmer Dr., Brooklyn, N.Y. (S)

Gordon, Robert N., Manufacturing Engineer. **Mail:** 6009 W. Pico Blvd., Los Angeles 35, Calif. (A)

Greenberg, Raymond, New Inst. for Film and Television. **Mail:** 149 Avenue C., New York 9, N.Y. (S)

Jantzen, Charles A., Photographic Analysis Co. **Mail:** 582 E. Seventh St., Brooklyn, N.Y. (M)

Johnston, Frank B., Sr., Chief Photographer, Philadelphia Inquirer. **Mail:** 1417 Dorset Lane, Philadelphia 31, Pa. (A)

MacDonald, Joseph W., New Inst. for Film and Television. **Mail:** 2414 Sullivant Ave., Columbus 4, Ohio. (S)

Mahoney, William J., Chief Audio Engineer and Owner, Cinecorders. **Mail:** 1730 Kleemeier St., Cincinnati 5, Ohio. (A)

Maloney, T. J., Producer-Director, KEYL-TV, Transit Tower, San Antonio, Tex. (M)

McLaughlin, Charles D., Projectionist, Southland Drive-In Theatres. **Mail:** 5655½ Huntington Dr., Los Angeles 32, Calif. (A)

Miceli, Ernest, Film Editor and Experimental Cinematographer, WOR-TV. **Mail:** 1745 W. Ninth St., Brooklyn 23, N.Y. (A)

Miller, Eugene S., Development Engineer, Eastman Kodak Co. **Mail:** 123 Heberton Rd., Rochester 9, N.Y. (M)

Niehus, Murray H., Engineer, Cliffords Theatre Circuit. **Mail:** 313A King William St., Adelaide, South Australia (A)

Norbury, Alfred S., Engineering Aide, Corps of Army Engineers. **Mail:** 3526 Harrison St., Kansas City 3, Mo. (M)

Nordbye, R. B., Motion Picture Photographer and Director, Great Lakes Prod., Inc. **Mail:** 208 North Hale, Wheaton, Ill. (A)

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Stoddard, William C., Boston University School of Public Relations. **Mail:** Cochituate Road, Wayland, Mass. (S)

Tucker, Morris H., Technician, Columbia Broadcasting System. **Mail:** 1530 Archer Rd., Bronx 62, N.Y. (A)

Wirth, Charles H., Project Engineer, Rangertone, Inc. **Mail:** 78 N. Spring Garden Ave., Nutley, N.J. (A)

Zampari, Carlo, Studio Manager and Associate, Studios Vera Cruz, "São Bernardo do Campo," São Paulo, Brazil. (A)

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Allen, Eugene S., Jr., Cameraman and Editor, Video Films. **Mail:** 870 Newport Ave., Detroit 15, Mich. (S) to (A)

Brauer, Howard H., Chief Electronics Engineer, Bell & Howell Co. **Mail:** 1020 Lawrence Ave., Chicago 40, Ill. (A) to (M)

Hufford, Robert G., Physicist, Eastman Kodak Co., 6706 Santa Monica Blvd., Hollywood 38, Calif. (A) to (M)

Jones, Lt. Harold, Jr., Photography Director, U.S. Signal Corps. **Mail:** Apt. 9A, 2026 Magill Dr., Fort Monmouth, N.J. (A) to (M)

Mann, R. G., Chief Engineer, Pathé News, 625 Madison Ave., New York 22, N.Y. (A) to (M)

Rockar, Lt. William F., Signal Corps, 301st Signal Photo Co., Camp Gordon, Ga. (A) to (M)

Svancara, V. J., Chief Sound Engineer (Motion Pictures), Wright-Patterson Air Force Base. **Mail:** 1228 Epworth Ave., Dayton 10, Ohio. (A) to (M)

Tamer, James S., Photographer, Sandia Corp. **Mail:** 3216 A. St., Sandia Base, Albuquerque, N.M. (A) to (M)

Zimmermann, August H., Engineer, DeLuxe Laboratories, Inc. **Mail:** 1090 Trafalgar St., West Englewood, N.J. (A) to (M)

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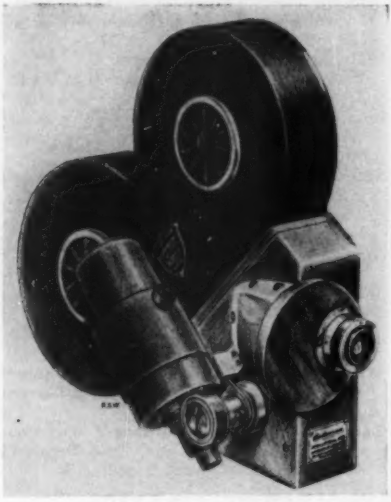

A 35-mm recording camera to fill the needs of industrial and research analysts has been designed by A. P. Neyhart, Chairman of the SMPTE's Subcommittee on Industrial and Research Photography, and H. G. Cunningham, camera designer, Hollywood. The Automax, as the new instrument has been named, is being tooled for production in the form shown above by the Guild Laboratories, 6264 Sunset Blvd., Hollywood 28, Calif., with which Neyhart is associated.

Neyhart is the designer of the camera for surgical photography which has been described in the JOURNAL (p. 747, June 1950).

The Automax can be operated, locally or by remote control, at interval rates from one exposure per hour to five exposures per sec and at pre-set cine rates of from 10 to 48 exposures per sec. Film exposure is the same for both interval and cine operation. An external intervalometer is required for automatic sequence operation. A 400-ft Mitchell magazine is standard in the present design but other capacities may be used. The standard design is for an acceleration range of 10 *g* vertical and 5 *g* horizontal, but a special combination is available for greater acceleration loads. A film-driven switch actuates an electric footage counter and also gives remote indication of camera operation. Several types of motors are available for field or mobile use. Power requirements range from 10 w, d-c, to 115 w, a-c, depending on application. Frame registration is accurate to 0.003 in., adequate for motion analysis and motion picture projection. An intermittent movement pin is used to transport and register film.

The camera is 6 × 5 × 2¼ in., with motors extending from 2 to 3 in. on one side. The weight, with aircraft motor, loaded 400-ft magazine and lens, is 12 lb. It is constructed to withstand temperatures ranging from −40° to 160°F.

With a new double-function, mercury arc-lamp power supply, manufactured by the Huggins Laboratories, 778 Hamilton Ave., Menlo Park, Calif., either direct-current or single-flash operation of AH-6 or BH-6 mercury-vapor arc lamps may be obtained from 115-v, 60-cps power. Direct-current operation provides steady light, while pulsed operation gives a brilliance about 200 times greater, with a duration of approximately 10 μsec. Either mode of operation can be selected from a single switch. With d-c setting, the power supply delivers 1 kw, 1.2 amp at 800 v. Open-circuit voltage of 1700 v is supplied for starting the lamp. Standard d-c ripple is about 5%, but lower values can be supplied in special units. With flash operation, the 10 μsec pulse at a power of approximately 2.5 watt-sec is provided by a power capacitor discharging through the lamp by means of a thyratron-controlled spark gap. Maximum repetition rate is 6 pulses per min.

The unit is mounted in a standard relay rack cabinet, and its over-all dimensions are 22 × 31 × 15 in. The manufacturers suggest its application to high-speed, Schlieren, shadowgraph and interferometer photography.

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